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TELESCOPE MAKING 46

The magazine *for, by,* **and** *about* **telescope makers!** **Winter 1991/92**

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THE COMPLETE ALL-ISSUE INDEX

TELESCOPE MAKING #46

The magazine for, by and about telescope makers!

Editor: Richard Berry
Associate Editor: Peter Ceravolo

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Editorial

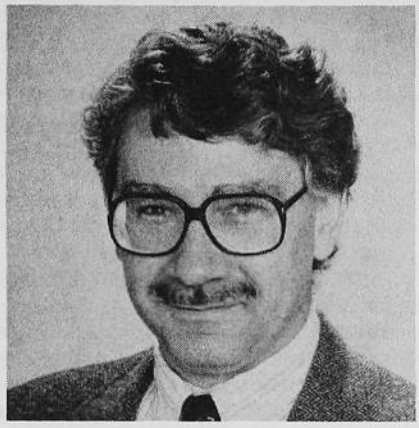
It is with great sadness that I announce that this is the final issue of *Telescope Making*. After a careful analysis of *TM*'s long-term past financial performance and its prospects for future growth, Kalmbach decided to end publication with the current issue. You will soon receive a letter from Robert Maas, the Publisher of *Telescope Making* and ASTRONOMY, offering to replace any outstanding issues of your *Telescope Making* subscription with the dollar-equivalent in issues of ASTRONOMY.

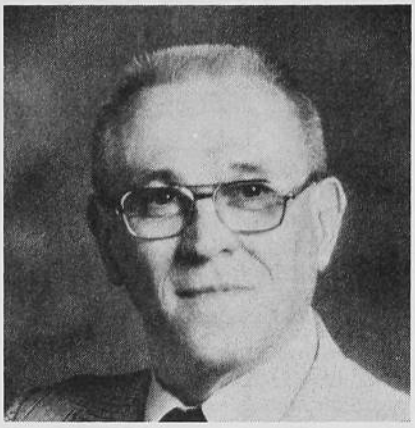
I would also like to announce — without sadness —that after sixteen years I am leaving Kalmbach and ASTRONOMY to take up full-time writing. With two books in the works and several more in the offing, I expect to be busy, productive, and happy. ASTRONOMY was a great adventure, but after sixteen years, it's time to begin a venture of my own.

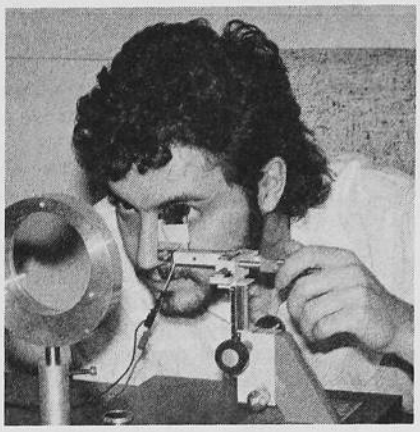
My immediate project is writing a how-to book about CCDs that will complement my last book-and-software production, *Astronomical Image Processing*. If you're into CCDs or image processing, please feel free to drop me a line. I'm on the lookout for great images, hints, tips, and your ideas to include in the book.

Gazing fondly back on the twelve years since Bob Cox and I founded *Telescope Making*, I realize that it's been a rich and satisfying

TELESCOPE MAKING'S EDITORS







time for me. In those years I've travelled the country and met hundreds of you, talked with you 'til all hours of the night, broken bread with you at conference tables, looked through telescopes with you, edited your stories, and had a great time. Even though I am leaving Kalmbach, I plan to remain active — perhaps even become more active — in amateur astronomy.

This year I'll be speaking at the Winter Star Party, and I'm sure I'll meet many *Telescope Making* readers at this year's Texas Star Party, the Riverside Telescope Makers Conference, Stellafane, and Astro-Fest. See you there!

I want to thank all the ASTRONOMY and Kalmbach people who helped Bob, Peter, and me put together over 2,500 pages of *Telescope Making* magazine. Long overdue thanks go to Kate Bond (alias Katherine King) for her painstaking attention to the first 25 issues of *Telescope Making*, and to Rhoda Sherwood for proofreading and shepherding all of the most recent issues through production.

I also want to thank the Kalmbach production department (and Michelle Hankes in particular) for relieving me of the day-to-day production headaches in the last year or so, and Brian Visser who for two years took over the advertising Blue Pages.

Credit is also owing Bob Maas, *Telescope Making*'s long-suffering publisher, and the guy who was gutsy enough to gamble on a magazine that both he and I knew would always have a small circulation. (Although Bob's background is accounting, he was "creative" on behalf of *TM*.) It's because of Bob that we had twelve years of *Telescope Making*.

Telescope Making's successful twelve-year run is due in no small part to our faithful and reliable printer, Port Publications of Port Washington, WI. My warm thanks go to Dennis Nemitz and his fine camera and press crew — without Port's quality work at low, low prices *Telescope Making* would never have been started at all.

I owe special thanks to two individuals who contributed greatly to the recent strength of *Telescope Making*, associate editor Peter Ceravolo and editorial assistant Tracy Staedter. Peter, as *TM*'s readers all know, brought a wave of fresh editorial ideas to the magazine and was hard at work rounding up new stories that might have strengthened the entire hobby.

In *TM*'s last year, Tracy took on many of the layout and desktop-publishing duties, and played an important role in getting each issue done on schedule. Her enthusiasm and fresh ideas made *Telescope Making* a stronger and better magazine, and Tracy's the one who compiled the comprehensive index to all 46 issues of *Telescope Making* in this issue. Thanks for your help, Tracy!

In the final analysis, though, it is this magazine's readers who have made it what it is. It is to you, more than anyone, that I owe the pleasure of editing this magazine. As I look toward the future, I'm sure that we will meet again.

Richard Berry
Editor

P.S. I've met a lot of you over the years, talked telescopes and optics, and I would love to hear how your projects are going. You can write me c/o Kalmbach or directly to my home at: RR#1 Box 58A, Cedar Grove, WI 53013. Stay in touch. My phone number is (414) 285-3305.

Letters

The Landscape of Amateur Astronomy

Richard/ A few days ago, I heard that *Telescope Making* would cease publication with its next issue. As an original subscriber to that magazine, I find this news sad indeed.

Relative to the size of its audience, *Telescope Making* is the most influential periodical of its time and is most responsible for the landscape in amateur astronomy as we know it today.

For example, in the January 1973 issue of *Sky & Telescope* is an article on the San Francisco Sidewalk Astronomers replete with pictures of the now-famous Dobsonian telescopes. Although the article talks about the fine views visible in these instruments, the author apparently had no insight into the revolutionary possibilities offered by the Dobsonian's simple technology. Six years passed before *Telescope Making* lit the spark of this revolution.

Telescope Making, not a Gleanings column.

Today companies such as Obsession make nothing but Dobsonians; others, such as Coulter, have made over their manufacturing operations to reflect the demand for Dobson-style telescopes.

Telescope Making has offered professional people like Peter Ceravolo, the late Bob Cox and others a forum to share their knowledge with the less fortunate. It has spearheaded the drive for better optical quality in amateur instruments. It has seen the publication of articles on everything from schiefspieglers to eyepieces to apochromatic refractors. And most of all, it has given amateurs a watering hole where they could address their love of telescope making.

THE BRIGHT SIDE

Like most telescope makers, I suppose I took the existence of *Telescope Making* for granted. I was working on numerous articles and thinking of topics for future issues. It is a tragedy to learn suddenly that there aren't enough of us to make publishing this magazine financially viable.

The news of *TM*'s demise threw me off balance because I had been hounding the movers and shakers in the telescope making community to write articles about their favorite projects so that we could all benefit from their experience and knowledge. The demise of *Telescope Making* means that most of these stories will never be told to an audience so large and so dedicated.

Telescope Making has served the astronomical community well because it has provided a home for articles that, for entirely valid and sensible reasons, could not be published in ASTRONOMY and *Sky and Telescope*. Furthermore, *Telescope Making* has been outspoken, hard-hitting, and controversial. When we published articles and letters telling of the sad state of optical quality in commercial instruments, people listened. The end result was better telescopes for all amateur astronomers.

Telescope Making could also delve into advanced topics and get technical as the story demanded, digging deep into a subject in a way that no other magazine could. And from all this, both we and the readers learned new things and gain new insights of how the instruments we use to pursue the hobby of astronomy work and more importantly, how we can improve them.

I am disappointed at the loss of *Telescope Making* not only because I was involved with only five issues but also because I didn't have the opportunity to cover much new ground that needs attention. For example, this issue of *TM* covers aluminizing and how the amateur telescope maker can get into it.

Another theme issue I was planned would have dealt with optical design and how it could serve the telescope maker. The time would have been ripe for *Telescope Making* not only because fast computers have become affordable, but also because powerful software for optical design is finally available.

Amateur telescope making will not come to a screeching halt with the last issue of *TM* magazine, but I am sure it will suffer. Communication among telescope makers is vital for this hobby grow. And *Telescope Making* had become the primary means of sharing, refining, and developing ideas.

For over fifteen years, I have eaten, breathed, and *lived* telescopes. I have learned a lot in those years, and became a professional optician. I looked forward to sharing what I have learned with you and learning more from you through this magazine.

But looking on the bright side, maybe now I'll do as my wife has long suggested and get a life!... Maybe.

Peter Ceravolo
Box 27092
Gloucester, Ontario K1J 9L9
CANADA

No other magazine does that.

Mr. Berry, did we ever ask you to print *Telescope Making* on fancy paper? Did we ever ask for color photographs? Did we even ask you to publish on time?

It is rare that such a homely publication receives so much love from its readers. Or respect.

I guess you know where I stand. Thank you for taking the time to listen to my views.

Richard Baier
2169 Haviland Dr., Apt. 10
Columbus, OH 43207

Many Thanks!

Richard/I want to thank you, Bob Cox and Peter Ceravolo for the incredible job you all have done over the years. The amount, type and quality of knowledge that has passed from a few to many hands via *TM* is beyond simple description. My latest telescope, which you saw at Hidden Hollow, would have surely been a completely different telescope if it weren't for *TM*. There must be fifty points of detail that were lifted from the pages of *TM*. But, certainly, without your — Richard Berry's — personal effort and many years of dedication and hard work, none of this would have ever come to pass.

Even though I am a contributing editor to *Deep Sky*, I will mourn the passing of *TM* more than that of *Deep Sky*. Newsletters abound that deal with observing. There are few, if any, other conduits of *TM* information that could dedicate as much space for the advancement of telescope building.

It is but a pipe-mounted dream for myself and many other (perhaps about 8,000?) readers that perhaps some other means can be found to continue the magazine, even if it is in a reduced format. Anything is better than nothing at all.

Robert Bunge
8814 Hawthorne Ln. #203
Laurel, MD 20708

Needing a New Tool

About seven years ago I bought an 8-inch Newtonian. It was a basket-case, but I have all the parts (minus the tube, which was a stovepipe). The only part I would like to keep is the primary mirror, but there's a problem: it's an f/15 and I would like to regrind it between f/6 and f/8, but I don't have the tool used to grind it. I've read your *Build Your Own Telescope* and Jean Texereau's *How to Make a Telescope*, and I've been looking for articles in *TM*, but I haven't found anything on this subject at all.

I've been subscribing to *TM* for about 3 years, but I am totally new to optical fabrication and as yet don't have any tools or supplies. I anticipate that it may be easier and cheaper to start from scratch, but I would like to make this mirror work if possible. Any and all suggestions would be welcome.

Mike Curtin
1377 E. Citrus #313
Redlands, CA 92374

— It seems a shame to use a finished, working mirror (?) as a raw glass blank, and my first reaction is to purchase a new blank and a tool and start from scratch. If you must *regrind the mirror, the existing curve is quite shallow so you can simply purchase a tool and start grinding. If anyone in the TM readership has a suitable tool they'd be willing to sell to Mike at swapmeet prices, please write to him.*

Sooty Knife-Edge for Mirrors

Richard/ I have often looked at the illustrations of the Lyot test in Texereau's book and wondered if there is a simple way of getting

these results — there is!

Cut a microscope slide into pieces about 1 inch square. Give one side a coating of soot from a candle flame, leaving it just transparent, and wipe half of it clear, to give a clean straight edge. Use this in place of the knife edge in a Foucault test with the soot towards the mirror. The effect appears just after the soot cuts off the direct beam. It needs a bright, but not very narrow, slit.

The appearance is caused by interference between the weakened direct beam coming through the soot, and the scattered light coming through the clear glass. The surface of the mirror shows up like a ploughed field. Small polisher work looks like a nightmare.

The optimum density of soot is best chosen by trial and error, and probably depends on the mirror surface quality. Make several soot slits and pick the best.

John Fletcher
421 Derby Road, Lenton
Nottingham NG7 2EB
UNITED KINGDOM

Wave-Testing for Mirrors

Richard/ I was interested in your comments about Peter Ceravolo's comparisons of 1-wave, $^1/_2$-wave, $^1/_4$-wave, and $^1/_{10}$-wave mirrors in *Telescope Making #43*. I think anyone with a serious interest in observing takes advantage of every opportunity to compare telescopes, but tests under controlled conditions with mirrors of known quality are rare. I have always felt that the true test of a telescope was the ability to see low contrast details. This has usually been taken to mean subtle detail on the planets — but deep-sky objects also exhibit subtle detail — and can in themselves be a subtle detail.

According to Jean Texereau in *How to Make a Telescope*, "Francon, studying planetary detail of minimum contrast, found that a wavefront defect of $^1/_{16}$ wave begins to be objectionable." Texereau and others also claim that a less accurate mirror is more sensitive to seeing.

It would be very helpful to *know* what accuracy is really required and what is available. A great many stories make the rounds of amateur gatherings, but there has not been a lot of careful qualitative testing on either question. The recent interest in optical quality and published tests of a small number of telescopes and telescope objectives has been welcome, but I think we are far from knowing much about the quality

AMATEUR TELESCOPE MAKERS JOURNAL

When a magazine dealing with computers, guns, fashion, or sports goes out of print, those loyal to it are understandably disappointed. However, there are so many publications dedicated to these subjects that a new source of information and enjoyment may be only 3 inches away on the newsstand. With the loss of *TM*, readers do not have choosing an alternative as an option. With its demise, many of us who could never get enough information anyway have nowhere to turn.

Therefore, I have called upon a number of friends to help me in creating a vehicle to gather and propagate material to ATMs all over the world. The vehicle is to be a non-profit publication called *Amateur Telescope Makers Journal*.

ATM Journal will be a quarterly publication operated through a network of ATMs who have the time, talent, concern, and drive to keep the spirit of *Telescope Making* alive. *ATM Journal* will be published by the newly formed Amateur Telescope Makers Association, a group created solely for the purpose of promoting advances in telescope making and related topics. The first issue will be mailed by March 1.

ATM Journal is not affiliated with *Telescope Making* in any way and maintains none of *TM*'s officers, assets, or liabilities.

The directors of *ATM Journal* currently consist of the following individuals: R.A. Buchroeder, John Gregory, Diane Lucas, Harrie Rutten, Martin Van Venrooij, and myself. Each director, acting as a regional editor, will take in proposed articles from a certain geographic area, edit material, work with the author, and pass on the most timely articles for further editing and approval by other staff members.

The format for *ATM Journal* will be quite similar to that of *Telescope Making*. However, because we will be calling upon a network of local associate editors and specialists, we anticipate being able to bring members of the ATM community closer together by offering articles highlighting the achievements and aspirations of local groups and individuals.

Those who wish to join the Amateur Telescope Makers Association and receive four issues of the *ATM Journal* may do so by sending a check or money order for $20.00 to:

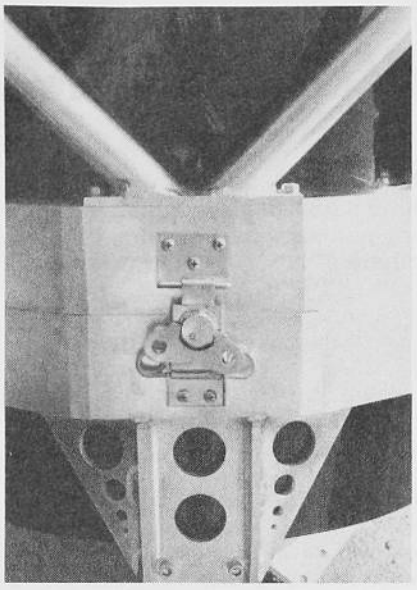
Amateur Telescope Makers Association (ATMA)
c/o William J. Cook
16930 20th Drive SE
Bothell, WA 98012

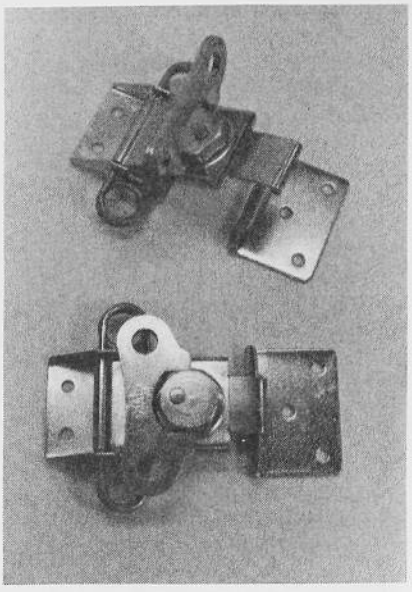
For now, until the infrastructure has been firmly established, manuscripts and letters to the editor may be sent directly to me.

As part of our spirit of partnership, we would ask that whenever possible, manuscripts be sent in a common word-processing format or ASCII file, so it might be brought directly into our desktop publishing program with a minimum of expended time and energy. *Telescope Making* was "The magazine for, by, and about telescope makers." With *ATM Journal*, this philosophy has not been altered . . . merely intensified.

William J. Cook
Seattle, WA

— I was extremely pleased when Bill Cook first called and told me of his plans to found a new magazine that will serve the community of amateur telescope makers. As Bill has noted, ATM Journal *is not affiliated in any way with Kalmbach Publishing Co., but is an entirely new and different magazine. I am sure that I will join many of the former readers of* Telescope Making *as a reader of the* ATM Journal. *— Richard Berry*





available. It would be very interesting to know how good the best optics are. How well do the best amateurs do? How do the custom mirror makers, past and present, do? What about the professionals?

It is usually claimed that beginners don't need quality optics because they can't see or appreciate the difference. I wonder if this is really true. You don't learn to play a good game of tennis or chess by playing someone worse than you — can you really learn to see what a telescope can show you with mediocre optics?

Alan French
R.D. 4 Box 205A
Scotia, NY 12302

— Peter's mirrors were shown at Stellafane and tested by a large number of observers on Saturday evening. I participated in the testing and listened to the comments of those around me. My general impression was that at least some of the observers could not distinguish between the $^1/_2$-wave mirror and the $^1/_{10}$-wave mirror. I understand that the results will be published in a future issue of Sky and Telescope.

Panamanian Astronomical Group

Richard/ I was very happy receiving through my friend Dr. Mel Boreham, *Telescope Making #43* which includes the article I wrote about the building of my telescope. I really appreciate the finishing touches you put in the text; they make the story more interesting and professional. Since I changed my office address last year, I sent it to you, but apparently it was missing in the mail. Please let your readers know about our association's new address.

Luis A. Harris
Asociación Panameña
de Aficionados a la Astronomía
Apartado Postal 6-7257
zona 6A El Dorado
Panamá, República de Panamá

Separating Cemented Lenses

Richard/ In *TM#26*, Bob Cox described a method for separating the elements of cemented lens such as those in eyepieces or small objectives. However, I have found a much better way of separating lens elements: soak the glasses in lacquer thinner made by Mastercraft and carried by Canadian Tire here in Canada.

The components of lacquer thinner are methyl alcohol, acetone, and toluene. Because the mixture is poisonous and flammable, it should be used only in a well-ventilated area. It will also dissolve pitch used in polishing mirrors and lenses.

After the lens elements are separated, the next step is to follow the instructions in *TM#28*, pages 16 to 19, to bond the lens elements back together again. For separating cemented lenses I would not advise anyone to follow the directions in this article — it is far too harsh and time consuming a method.

Daniel Kahraman
963 Erie E.
Windsor, Ontario
N9A 3Y9
CANADA

Picture Shows San Angelo Group

Richard/ Thank you for publishing the picture of our contingent at this year's TSP (page 21); the caption should read: Members of the San Angelo Amateur Astronomy Association (Texas). Pictured from left to right: Cindy Rowland, Chadd St. Clair, Kevin Mace, and Bruce McKowen, pose beside the club's *12.5-inch f/7* Dobsonian that honors Dr. Roy E. Moon.

Kevin Mace
121-A Laura St.
San Angelo, TX 76905

Twist and Clamp

Richard/ I have discovered some clever attachment hardware called Twist Hatch Fasteners that could be used on break-down telescopes.

Twist Hatch Fasteners are very easy to use, working quickly and positively, with only a firm twist of the wrist. I have enough confidence in them that I use only three of the larger size (plus stainless steel locater pins) to fasten the 80-pound mirror/cell case on my 20-inch f/4 all-aluminum telescope. They are Twist Latch Fasteners made by Simmons, USA.

Bob Drew
12207 Aspen Dr. W.
Edmonton, Alberta
CANADA T6J 2B7

Anyone Know Franklin Wright?

Richard/ I just adopted a very old but useful-looking optical bench which Paul Zurakowski assures me was built and used some fifty years ago by the legendary Franklin Wright. Unfortunately, I know little or nothing about the man whose name is attached to the Wright-Schmidt camera. Now that I have a small piece of his life sitting in my workshop, I feel compelled to learn about him. Can anyone out there point me in the right direction?

Christopher Paul
3609 Buchanan St.
San Francisco, CA 94123

Computer-Assisted Observer

Richard/ I have recently upgraded my telescope mounting for use with digital setting circles. The mount works very well allowing me to find numerous objects in a very short time. The mount is left outside with a cover so set-up requires just minutes.

I have built a second mount, bolted to a tripod, for field use, star parties, etc. I would be glad to share these designs with anyone who shares my enthusiasm for this hobby.

Bill Russell
2254 Rockville Rd.
Suisun, CA 94585

Glass Pusher Syndrome

Richard/ On Saturdays a crew of five barrel walkers makes mirrors in my basement. Between visitors from previous groups and others who "just drop by," we have a lively time. The atmosphere is quite relaxed but to relax it a bit more, I posted the enclosed notice on my basement door. As you might expect, nobody was dismayed at the prospect of walking barrels for the rest of their lives.

Bill Herbert
1405 Inglis Ave.
Columbus, OH 43212

WARNING WARNING WARNING

These premises are contaminated with a malady known as Glass Pusher Syndrome. The GP Syndrome is characterized by an irrational compulsion to walk in endless circles around a barrel while sliding one circular disk of glass over a similar disk.

- - -

Those afflicted by the Glass Pusher Syndrome say their objective is to produce a curved surface on one disk which will reveal the secrets of the universe. Normal persons should view such grandiose notions with tolerance and sympathy generally accorded the mentally deficient.

- - -

In severe cases the GP Syndrome is a life-long disease. Friends and relatives of the victim are advised that no known remedy exists and gentle forbearance of the irrational behavior of their loved one is recommended.

- - -

The Management will not be responsible for any person contracting Glass Pusher Syndrome.

Inspire a Passion to Learn

Richard/ Let me express my appreciation for the enormous amount of professional effort you and your staff put into creating the *TM*s I have received. As a new subscriber, I find your articles a pleasurable diversion from the tasks at hand here in the Mediterranean. *TM#44* is chock full of superb and practical ideas and techniques. This is the sort of stuff I look for in your periodical — other magazines handle the basics and generalities well enough.

LT Paul Shankland, USN
Carrier Airborne Early Warning
Sqn 122 / Unit 60137
FPO AE 09507-6407

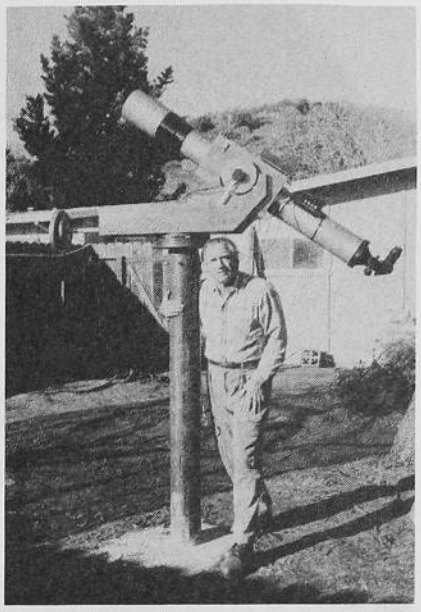
Dobfractor Madness!

Richard/ Enclosed are photos of my "Dobfractor" built around a 4.5-inch f/15 Thomas Cooke lens that I purchased earlier this year. The glass is in pristine condition, and was found in its original mahogany case. Of course, one never knows until a lens is put under test. Based on Cooke's reputation and the described condition, I took a chance, and am pleased that the glass performs in the tradition of fine 19th-century lenses. Through murky South Carolina skies, I have cleanly split 1.1" doubles and am currently enjoying fine views of Saturn.

This is an "interim" telescope until the lens can be permanently mounted in an aluminum tube. In the meantime, the Dob base rides atop an old C-8 tripod. It is shock-mounted using four high density felt pads (furniture leg pads) which provide smooth motion against the tripod top.

I have the good fortune to work in "refractor heaven" with regular access to a fine 6-inch f/15 Mogey and the former Princeton 23-inch Clark which continues to inspire students at Roper Mountain Science Center. I can, therefore, check on details seen first in the Cooke. I also have friends close by who share an interest in early instruments, including Bob Ariail whose remarkable collection includes three Cooke telescopes. Bob has been a great mentor and supporter of my projects — personal and professional.

Doug Gegen
1101 Roper Mtn. Rd., Apt. 290
Greenville, SC 29615



Mirror Knob Clarification

Richard/ Thanks for publishing the article "A Motorized Cassegrain Secondary" in *TM45*. You did wonders with the grainy prints I sent you.

I would like to clear up a possible ambiguity in the caption to the photo on page 8. The four knobs shown on the back plate do not all adjust the primary mirror cell. As explained in the text at the bottom of page 9, the top two knobs control the two orthogonal axes of the primary mirror, which requires only two non-interacting adjustments to move the primary mirror.

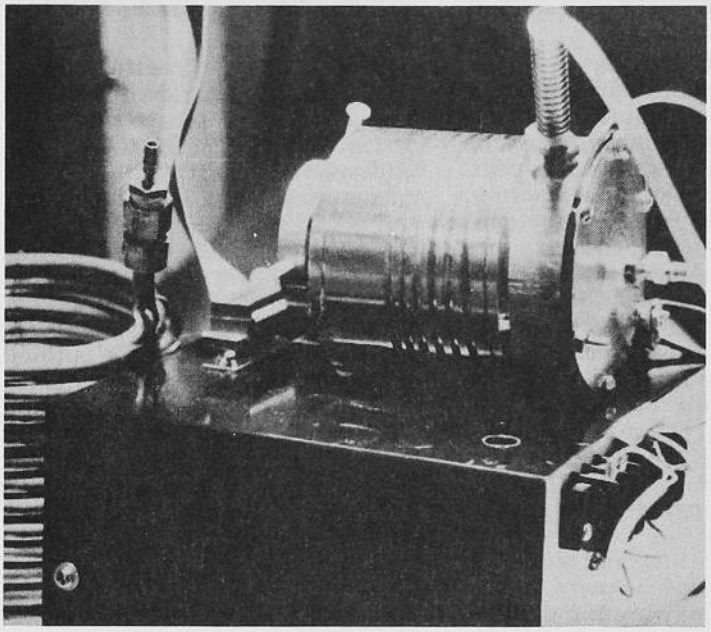
The two bottom knobs are attached to two $^1/_4$-inch rods running most of the length of the tube up to the double-gimbal mount of the secondary mirror. The ends of these rods are threaded and screw into nuts fixed to the inside of the tube. As one of the lower knobs is turned, its rod protrudes farther past the nut (or not as far, depending on the direction the knob is turned).

Each ring of the gimbal mount is spring-loaded against its respective rod end and, thus, rotates as the rod moves in and out, tipping the secondary mirror in one of its two orthogonal axes. Thus both primary and secondary mirrors are controlled from the eyepiece end of the Cassegrain telescope by knobs within easy reach of an observer concentrating on the image in his eyepiece.

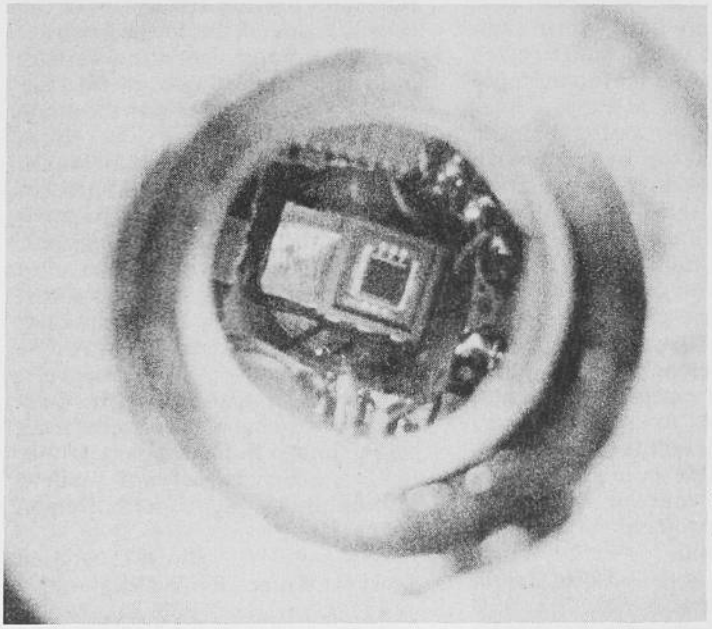
I hope this helps your readers understand Andy Tomer's design concept.

Mark Trueblood
Winer Mobile Observatory
P.O. Box 42556
Tucson, AZ 85733

How To Build A Basic CCD Camera



Here is what the first version of the CCD camera looked like.



The TC-211 chip seen looking down the barrel of the camera.

The Texas Instruments TC211 area image sensor offers the amateur telescope maker an opportunity to experiment with CCD astronomy at a reasonable price. The sensors we purchased cost $35 a couple of years ago. Great references on building CCD cameras such as *CCD Astronomy* by Christian Buil and inexpensive image processing software like Richard Berry's AIP program give amateur astronomers an opportunity to construct CCD cameras and then extract the full content of the information recorded by the camera.

Construction of a CCD camera requires experience with many subjects but so does the construction of a telescope. We constructed our camera using Christian Buil's book as a reference guide (as one uses Texereau for telescopes) and the *Texas Instruments 1987 Optoelectronics and Image-Sensor Data Book* as a guide to the TC211 CCD chip. The TC211 chip differs from the Thompson chips which are described in Buil's book so we will provide some background on the TC211 operation.

The main goal of this article is to present an alternative computer interface. The need to use a dedicated digital Input/Output (I/O) card for control of the camera was an undesirable aspect of Buil's camera. However, the printer port, which is present on most PC computers (including lap-top) appeared to hold some promise of functioning for the task, and it was converted into a general camera interface. Its performance is lower, than that of a true digital I/O card but it's free.

The PC Parallel Printer Port

Our software was designed to

use LPT1 as the control port. Most systems have LPT1 located at the base port address 378 hex, but if you decide to build a system like ours, you should check their manuals for the address of their system. The printer port uses a 25 pin DB style female connector and a cable made with 25-lead ribbon. Up to fifteen feet of cable fitted with a male DB25 connector can be used to connect the camera to the computer.

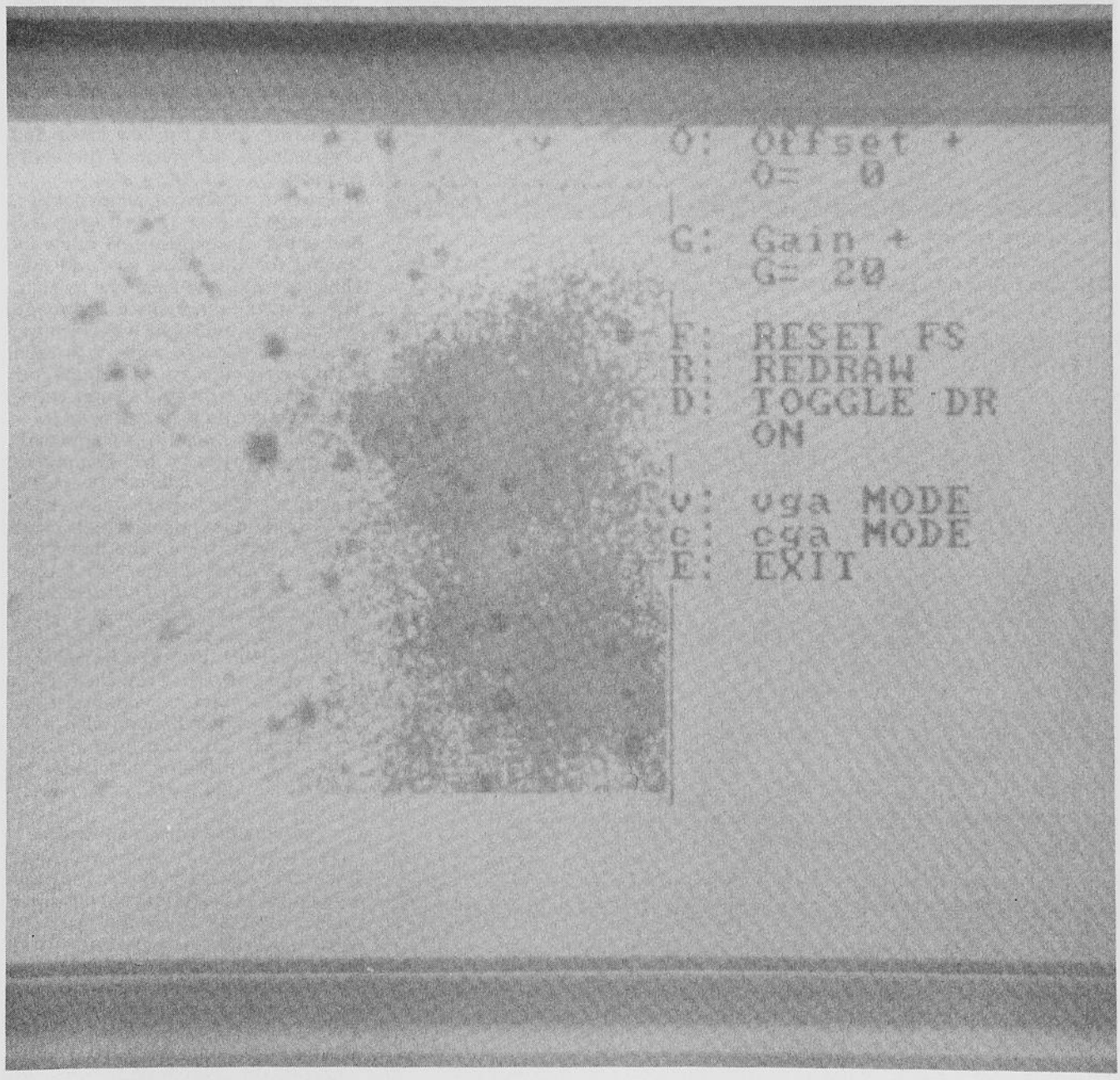
The data output latch of the printer port is used to generate the timing signals for the CCD chip. Data is written to the eight-bit data port which is at address 378 hex. Data bits zero through seven of the port are connected to pins 2 through 9. Most printer adapters have large capacitative loads on these data lines, which slow down the signals to reduce ringing and the generation of noise. The rise time of these lines must be restored with the use of Schmidt-triggered gates at the camera interface.

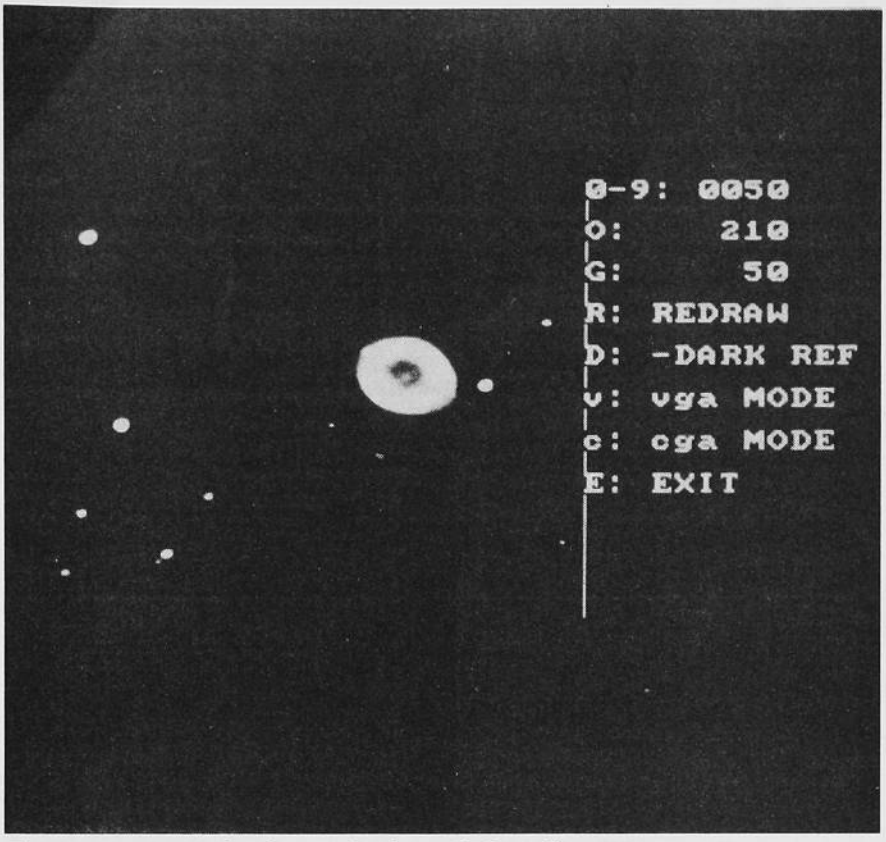
Unfortunately, the printer port does not have a complete 8-bit data-input system. The normal function of the data-input system is to determine the status of the printer. Four of these status input lines are used to read the ADC (Analog to Digital Converter) data. The status-port input address is 379 hex. Only bits seven through four are used for data. Obtaining eight-bit or twelve-bit data requires the use of a multiplexer at the camera interface. Data is restored through the use of logical *AND* which masks the lower four bits to zero. The four-bit data nybbles are then multiplied or divided to justify the nybbles before they are summed.

Computations are further complicated because bit seven is inverted. This bit is corrected with the XOR function which toggles the bit. As an alternative, the data line could be inverted by the camera hardware. On the DB25 connector, bit 7 connects to pin 10, bit 6 connects to pin 11, bit 5 connects to pin 12 and bit 4 connects to pin 13. Pins 18 through 25 on the DB25 connector are ground. The camera I/O interface and multiplexer circuitry are shown in Figure 1.

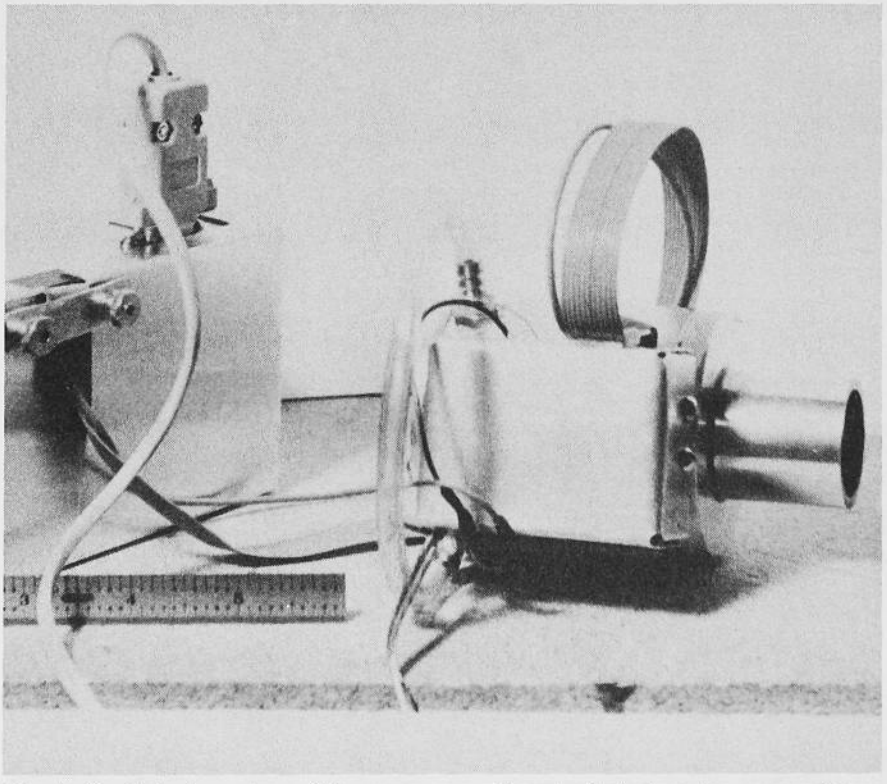
The TC211 CCD Chip

Texas Instruments uses a Virtual





The camera control software displays all the information necessary to operate the camera on the screen beside the last exposure that you have made. Both the CGA and VGA modes use 320-by-200-pixel graphics.



Here's the latest version of the camera and control electronics--a considerably tidier package than the first. Both the camera head and the control electronics fit into standart project boxes.

Phase process which simplifies the timing for the CCD. In our camera, only two clock signals are required to shift out the image data. We do not use the anti-blooming gate function.

The chip is organized as a 192 pixel by 165 line device. To obtain one image line from the chip, the IAG (Image Area Gate) input goes from a low state to a high state, the Serial Register Gate (SRG) input goes from a low state to a high state, the IAG input is set back to a low state and finally the SRG input is set back to a low state. Next, the line is read out with only SRG clocks. Pixels are shifted out by raising the SRG input to a high state then back to a low state.

When the SRG input is in the high state, the output is in the reset state. It is not possible to obtain the reference level as with the CCDs described in Buil's book because the reset is internally connected to the SRG input. When the SRG input returns to the low state, the output holds the value of the shifted pixel.

Prior to obtaining an exposure, the image area is cleared with 165 line shifts. An exposure is made by leaving the IAG clock low and toggling the SRG line from low to high. The chip does not have an image storage area and light will continue to strike the image while it is read out. This poses no problems for faint objects, but sub-second exposures require an external shutter.

When the exposure is completed, the image is read by 165 line shifts. Each line shift is followed by a serial readout. The serial register contains six dummy pixels which must be shifted out before the first pixel can be obtained. The 192 image pixels are then shifted out, converted to a digital format and stored. Another 12 pixels are present in the serial register after the image has been read out. These are dark reference pixels which are covered by a mask. Texas Instruments also sells a version of this chip without the mask and it contains 204 pixels by 165 lines.

Converting the Image to Digital

A twelve-bit Analog-to-Digital Con-verter (ADC) with an internal sample-and-hold amplifier converts the signal to one of 4096 levels. The output signal has a maximum peak-to-peak range of close to one volt. The specification indicates the saturation level is typically 600mV. The converter requires a signal which varies from zero to 10.0 volts.

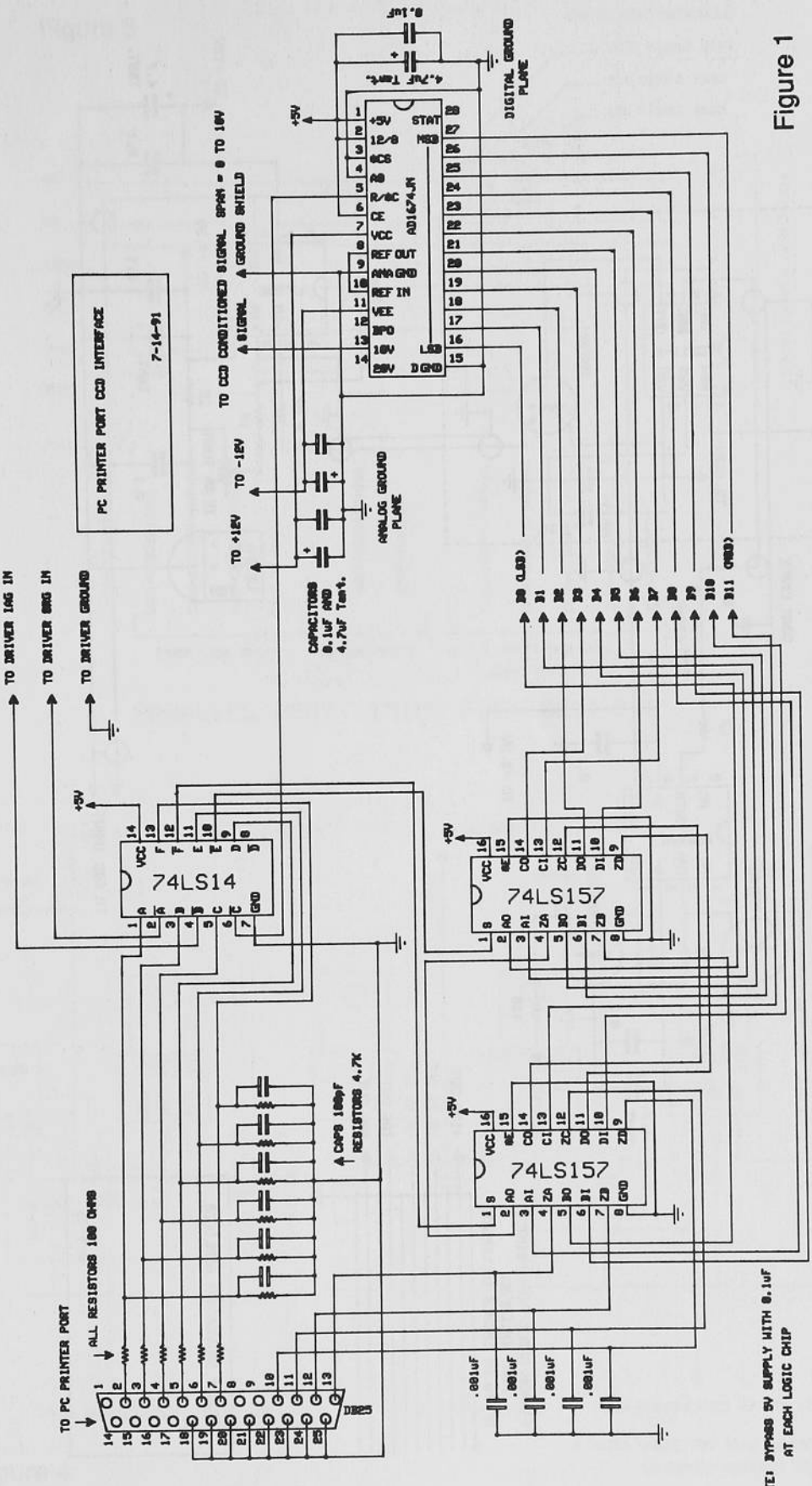

PC PRINTER PORT CCD INTERFACE
7-14-91
TO CCD CONDITIONED SIGNAL SPAN = 0 TO 10V
SIGNAL
GROUND SHIELD
TO +12V
TO -12V
ANALOG GROUND PLANE
DIGITAL GROUND PLANE
CAPACITORS 0.1uF AND 4.7uF Tant.
AD1674JN
74LS14
74LS157
74LS157
TO DRIVER IAG IN
TO DRIVER BAG IN
TO DRIVER GROUND
TO PC PRINTER PORT
ALL RESISTORS 100 OHMS
CAPS 100pF
RESISTORS 4.7K
DB25
.001uF
NOTE: BYPASS 5V SUPPLY WITH 0.1uF AT EACH LOGIC CHIP

Figure 1

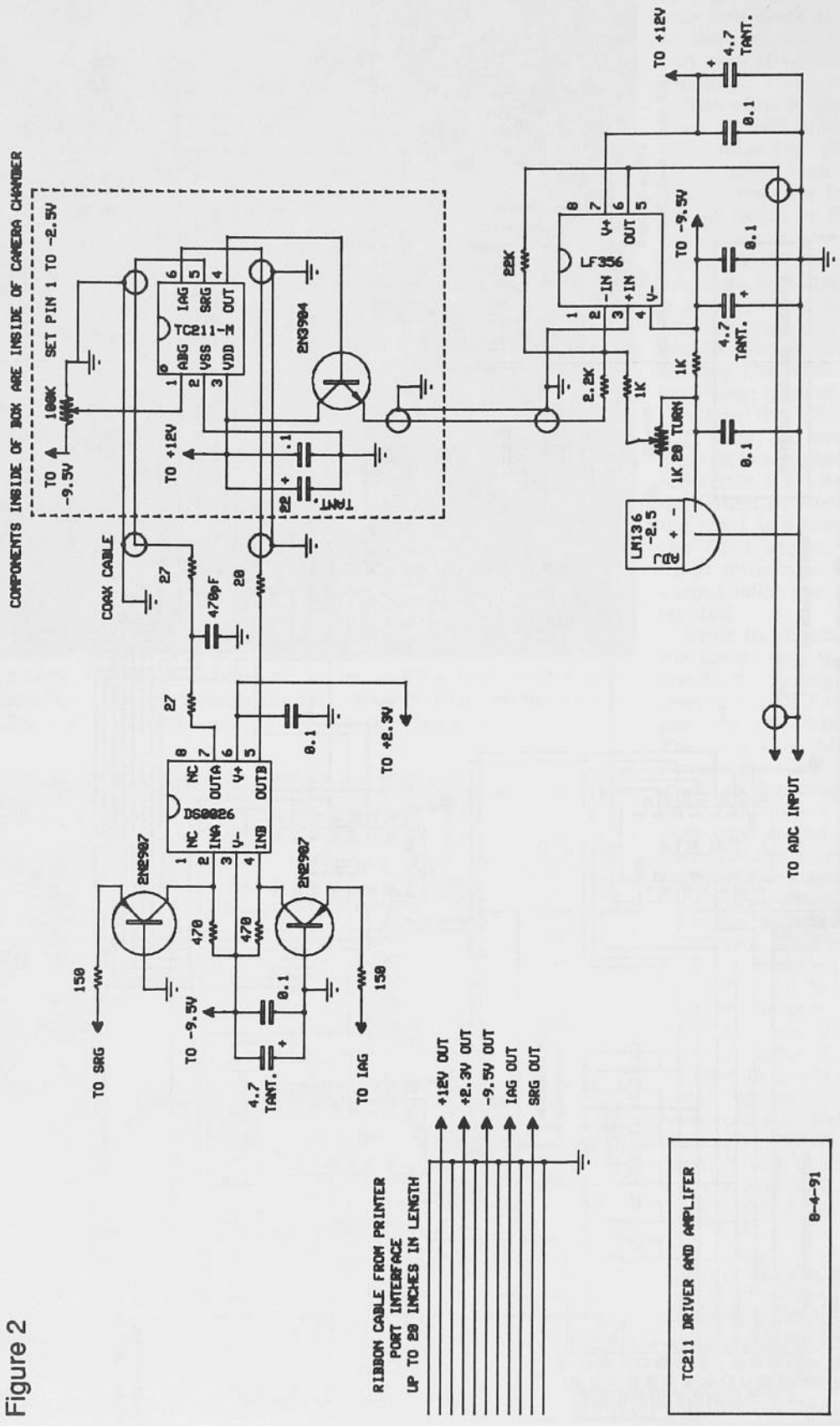
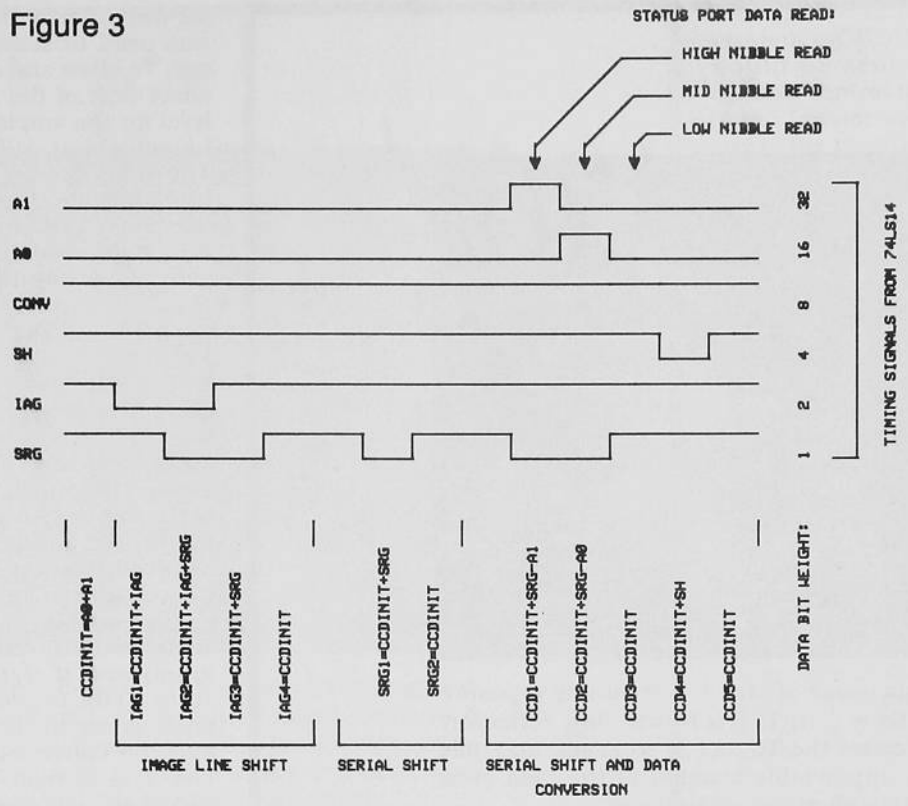

COMPONENTS INSIDE OF BOX ARE INSIDE OF CAMERA CHAMBER
TO -9.5V
100K SET PIN 1 TO -2.5V
TC211-1
ABG
VSS
VDD
IAG
SRG
OUT
TO +12V
2N3904
22
.1
TANT.
COAX CABLE
27
470pF
20
27
DS0026
NC
OUTA
V+
OUTB
INA
V-
INB
0.1
TO +2.3V
2N2907
2N2907
470
470
150
150
TO SRG
TO IAG
TO -9.5V
0.1
4.7
TANT.
RIBBON CABLE FROM PRINTER
PORT INTERFACE
UP TO 20 INCHES IN LENGTH
+12V OUT
+2.3V OUT
-9.5V OUT
IAG OUT
SRG OUT
22K
LF356
-IN
+IN
V+
V-
OUT
2.2K
1K
1K 20 TURN
LM136
-2.5
TO +12V
4.7
TANT.
0.1
TO -9.5V
4.7
TANT.
0.1
0.1
TO ADC INPUT
TC211 DRIVER AND AMPLIFER
8-4-91

Figure 2

Figure 3



PARALLEL PORT TIMING FOR TC211 CCD

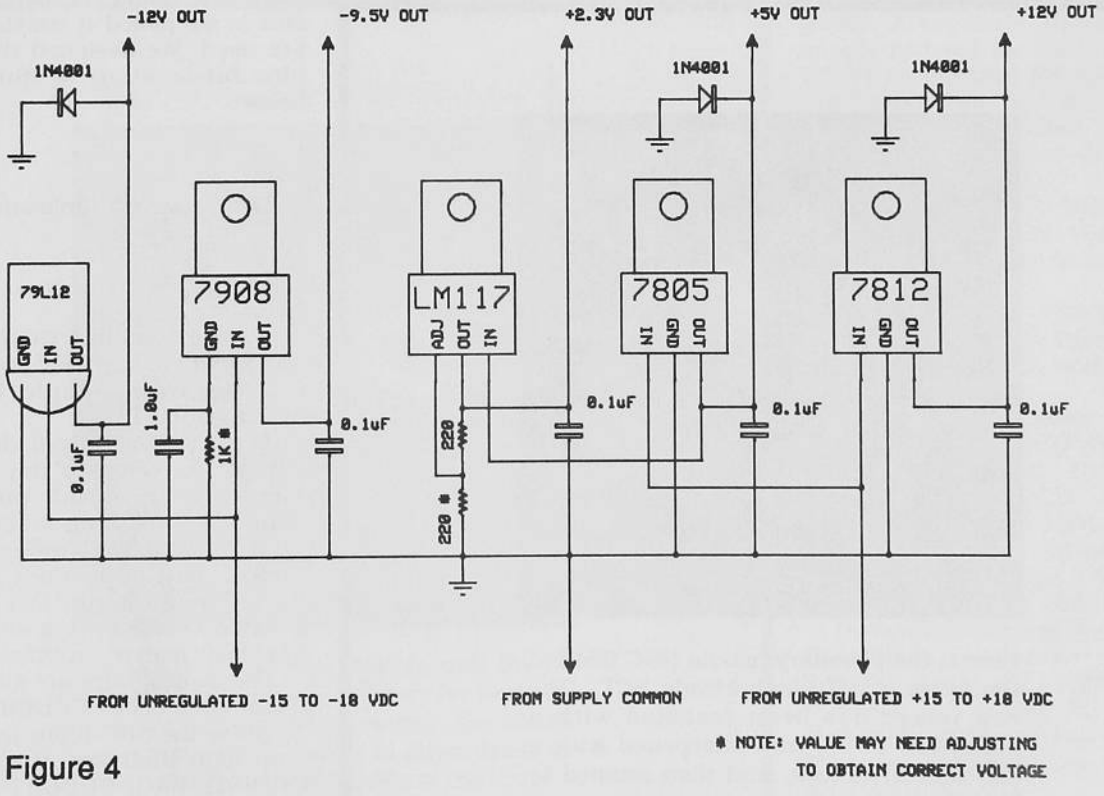


Figure 4

This image of M27 is a 2-minute exposure with a 6-inch f/5 Newtonian reflector. Because the TC-211 is so small, M27 fills an appreciable fraction of the field even with a short-focus telescope.

Here is the planetary nebula NGC 6543 at the focus of a 10-inch Meade SCT. The raw image has been rescaled with a power-law of 0.4 and sharpened with a 3x3 unsharp mask, and then zoomed to double size.

An amplifier with a gain of -10.0 was used to scale the output voltage. To allow and correct for the DC offset drift of the system, the reset level for the amplified signal should be set about 100mV above zero. The reset level can be converted and used for a reference point. Otherwise, set the zero integration time dark readout level just above zero. The amplified dark level is about 1.5 volts above the reset level. The CCD circuitry is shown in Figure 2.

The AD1674 converter is connected for stand-alone mode operation. Conversion is started after the data output (SRG goes low) is allowed to slew to the new level and settle (about five microseconds). Conversion is initiated by a high to low transition on the R/C input to the converter. The data outputs are only present after the conversion is completed (10 microseconds minimum) and if R/C is in the high state. Data is read after the SRG input is set to the high reset state and the conversion is completed. The data is read in three nybbles which are accessed through a two-bit address control of the multiplexer circuits. The address is sent out the printer port and the data nybble is obtained by a subsequent input of the status port.

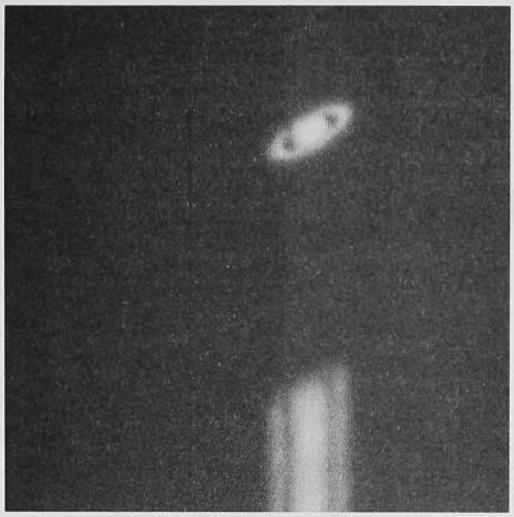
Programming the control interface is simplified if constant terms are used. We assigned the control pins bit-location weights shown below:

SRG = 1
IAG = 2
SH = 4 (sample/hold and convert)
CONV = 8
A0 = 16
A1 = 32

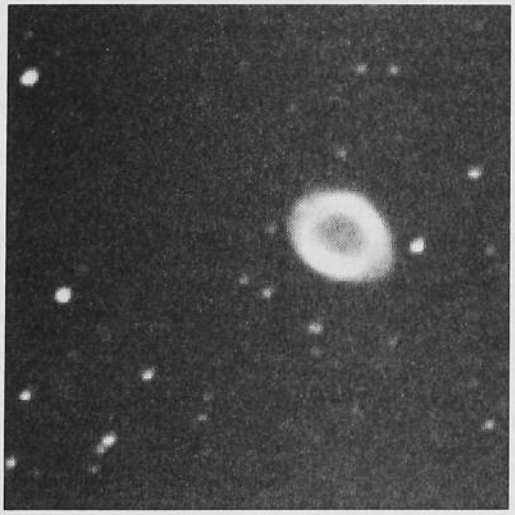
(We did not use CONV. COVN and SH can be used on systems with separate sample/hold and ADC modules.)

The data lines from the printer port are inverted by the interface. The correct timing polarity is obtained by adding a constant to set a low logic level and subtracting the constant to obtain a high logic level. The SRG and IAG lines are inverted by the drivers and positive level logic is used on these lines.

The control lines are all set to an initial state called CCDINIT=A0+A1. To pulse the SRG input to the CCD chip high then low, the sequence CCDINIT+SRG; CCDINIT would be sent to the printer port. The SH logic input to the converter is normally in the high state.



A prime-focus image of Saturn through the 10-inch f/10 Meade stopped down to 4 inches aperture. This image was shuttered with a special software routine that uses the chip in a half-frame mode.



This image of the Ring Nebula with the 6-inch f/5 telescope is among the first we took. To prepare it for printing, the image was exponentially scaling to show detail in both the bright and dark parts of the image.

To pulse the SH line low, the sequence CCDINIT+SH; CCDINIT would be sent to the port. The address control inputs to the multiplexer are normally in the low state due to the inverted logic.

To set the address line A0 high the value CCDINIT-A0 is sent to the port. A general timing sequence for the three basic operations: line shift, serial shift, and serial data conversion, are shown in Figure 3.

A simple program that uses MicroSoft QuickBASIC 4.5 to drive the interface is available from the authors. It uses an integral machine code driver for slower machines but includes a driver written in QB for reference. If you request the program, please send a 5.25-inch formatted diskette and a stamped, self-addressed diskette mailer.

Miscellaneous

The interface and CCD circuitry require little power. Well-filtered ±15VDC at 150mA is needed. The regulated voltages are obtained with the circuitry shown in Figure 4. The cooling system requires most of the power. Our system uses a Cambion model 801-2003-01-00-00 Peltier cooler which is operated at 3 amps and 5 volts. The back of the camera is an integral water jacket which is pumped by an electric fuel pump. A separate 12-volt 1-amp supply is used for the pump. The TC211 is specified for operation at –10C minimum, but we operate it down to the specified minimum storage temperature of –30C.

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References:

Buil, Christian, *CCD Astronomy: Construction and Use of an Astronomical CCD Camera*, Willmann-Bell, Inc., 1991.

Berry, Richard, *Introduction to Astronomical Image Processing*, Willmann-Bell, Inc., 1991.

Optoelectronics and Image-Sensor Data Book, Texas Instruments, pp 2-99 through 2-107, 1987.

Scott, M., Siegel, B., *Applying Modern Clock Drivers to MOS Memories*, National Semiconductor, AN-76, 1975.

Jourdain, R., Programmer's *Problem Solver for the IBM PC, XT, and AT*, Brady Books, 1986.

Making Mirrors: The Art of Aluminizing

Telescope makers don't make mirrors. They make mirror holders." Although I hadn't known Kevin Medlock very long at the time, I had already come to expect remarks like that from him. But Kevin is right. The sole purpose of the 500 tons of glass and steel in the 5-meter Hale telescope is to support a couple of ounces of aluminum on the mirror. The precisely polished disk of glass is merely a base for the aluminum coating that does all the work.

Like most TMs, I once thought that aluminizing was one facet of optical work forever beyond my reach. I have learned, however, that a resourceful and knowledgeable TM can assemble an aluminizing plant and coat mirrors at home. This article covers some of the fundamentals of aluminizing and tells the story of how I happened to acquire my own coating plant.

Most North American telescope makers ship their optics halfway across the country to a plant that specializes in amateur optics. Canadian amateurs must also cope not only with shipping but also with the complications of customs and all the associated red tape. If a coating plant is located nearby, it's usually a commercial shop where they don't know anything about astronomical mirrors, where coating chamber time is valuable and service is expensive, and where you aren't guaranteed a good job for the money (see "Coatings, Cosmetics, and Guarantees"). It can all seem one big hassle.

Several years ago I was whining to Kevin Medlock about the trouble I had getting a mirror coated up here in Canada. Kevin, an Oakland, California TM, caught me off guard; "Well, why don't you come down to my shop for a week or two before Riverside and we'll assemble a coating plant that you can take home with you!"

I thought he was kidding at first. Coating plants require equipment that is hard to get if you don't know where to look, and you pay top dollar if you buy new. But Kevin had already built two coating plants. His small one can handle a 16-inch mirror and the larger chamber can accommodate a 40-incher. Both coaters lived in his garage. Kevin ultimately convinced me that he was serious, and I convinced him that I was serious by mailing him the first check so he could gather the parts.

Pumps and Chambers, Chambers and Pumps

The major components of an aluminizing plant are a vacuum chamber (if it is glass, it's called a bell jar) large enough to handle the largest mirror one is likely to make, a baseplate to serve as the bottom of the coating chamber, a roughing pump (sometimes called the forepump) to evacuate the bulk of air in the vacuum chamber, a high-vacuum pump to bring the chamber down to coating pressure (usually an oil-diffusion pump), vacuum gauges and controllers to measure the air pressure in the system, tungsten filaments that evaporate the aluminum, transformers and associated electrical equipment to power the filaments, valves to control pumping, and a frame to hold everything.

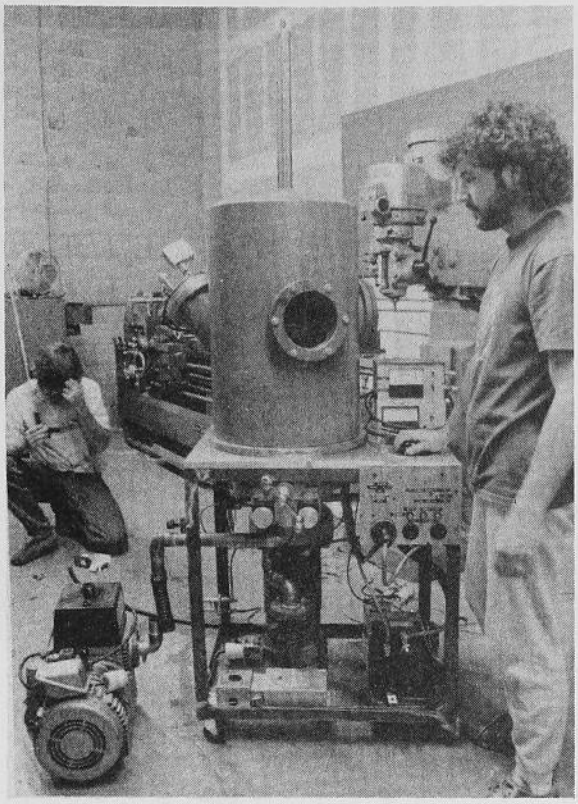
Clearly this much equipment is not trivial to assemble. Furthermore, a coating plant, even a basic one such as mine, requires a great deal of machine work. This is not meant to discourage anyone — I just want you to understand it's not something to undertake lightly.

Most of the parts were obtained at a very small fraction of the original prices from surplus yards in the Bay area. Kevin had been accumulating surplus vacuum equipment for years and already had a lot of the components I would need. The roughing pump, which needed a few new bushings, cost $50, and the diffusion pump added another $60. Kevin had a gate valve (the valve that goes between the diffusion pump and the chamber) lying around, and it already had a lot of the plumbing and valving necessary for the roughing pump built in. This greatly simplified construction and made the unit compact.

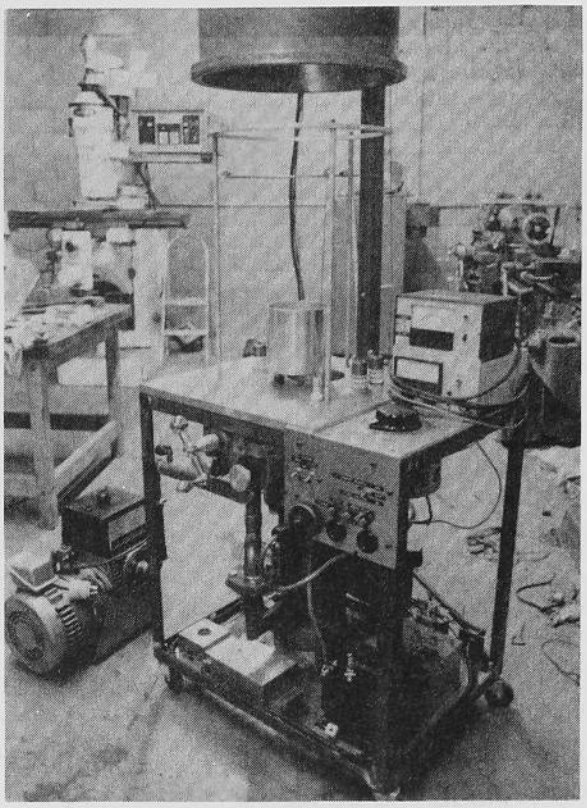
The most expensive component was an 18-inch stainless steel bell jar. It cost me $800 from a used equipment dealer. Kevin had a glass bell jar on hand, but wouldn't let me have it because glass bell jars can be dangerous. Kevin was once close to an evacuated glass bell jar when it imploded. Even with a blast shield, Kevin said that bits of glass flew in all directions at high velocities.

The chamber has two windows to view the interior. A third port holds the air admittance valve, a coarse vacuum gauge head, and a vacuum-operated cut-off switch that cuts power to the interior of the tank when it is at atmospheric pressure.

Although industrial coating plants are built into a large, heavy frame even when the chamber is small, for me it was important that the frame be compact because it would have to be squeezed through doorways and down stairwells to get to my workshop. That meant some custom work and designing a frame that could be knocked down and reassembled. The total for components came to roughly $1500. Over three weeks of work were required to assemble the system. Jobs ranged from basic plumbing and



The chamber as it neared completion in Kevin Medlock's shop. The author is standing by the plant while Kevin is planning his next move. The roughing pump, to the lower left of the chamber, is run by a three-phase motor that is operated through a phase converter so it can be plugged into a standard dryer outlet. The diffusion pump is mounted in the frame below the chamber.



The coating plant with the chamber raised to reveal the supports for the optics, the source shield which protects most of the tank and windows from getting coated, and the electrical feed-throughs that power the sources. The chamber rides the 2-inch square tubular steel column with the aid of 130 pounds of lead counterweights.

wiring to lathe and mill work. The frame was custom welded and the 3/4-inch-thick aluminum base plate (on which the tank rests and the diffusion pump is fastened) required Kevin's large mill to machine. We mounted all of the switches and fuses for the pumps and sources on a control panel. All of the assembly work was done at Epoch Instruments, the astronomical equipment manufacturing company that Kevin owns.

The Diffusion Pump

The diffusion pump deserves special attention since it is the key to achieving the low pressures necessary for coating. Amazingly enough, these pumps produce a very high vacuum with no moving parts. Here's how they work: The chamber and diffusion pump are initially evacuated by the roughing pump. The vacuum oil at the base of the diffusion pump is heated to the boiling point. The resulting oil vapor travels up a central tube to the top of the pump and then sprays downward.

Because the vapor is hot, the oil molecules are moving fast and they drag any air molecules with them toward the base of the pump. At the base of the pump, the roughing pump removes them. The oil vapor condenses on the water-cooled walls of the diffusion pump and returns to the oil reservoir at the base of the pump for another pass through the system. Ordinary 10W-30 won't work in an oil diffusion pump; it takes a special kind of oil that can stand high heat and is free of volatile components.

My system has an added refinement: a water-cooled cold-trap acts as a baffle. The cold surfaces help prevent escaped oil vapor from entering the vacuum chamber and coating the mirror's surface with oil. In a laboratory setting, the cold trap would be filled with liquid nitrogen, but this is obviously not practical for the home hobbyist. I run tap water through the cold trap.

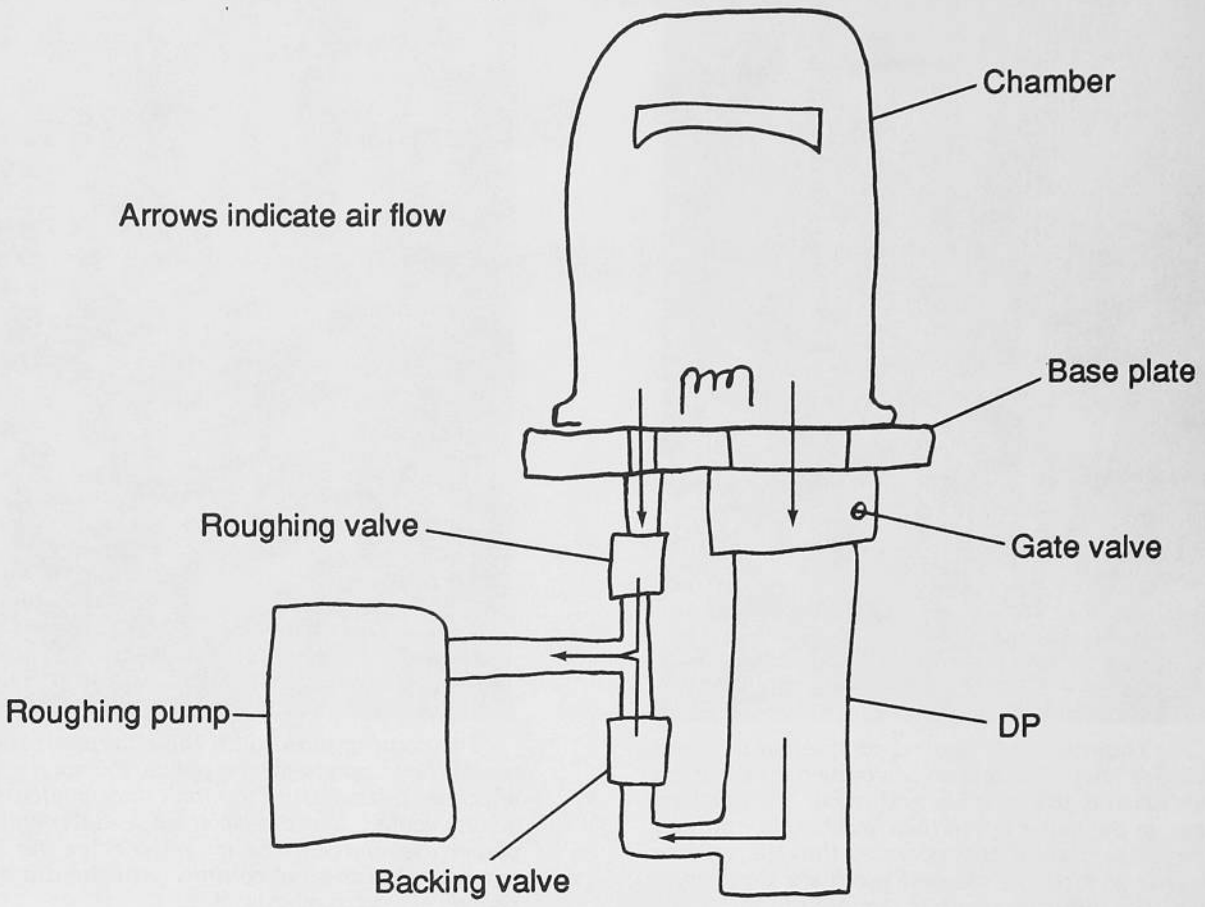
How to Run a Coating Plant

Making a vacuum and coating aluminum may seem a bit mysterious at first, but bear with me and I'll try to explain the basic ideas. What happens is this: the roughing pump removes air best at high pressure and the diffusion pump removes air at low pressure, so the two kinds of pump are used in tandem.

The diffusion pump is hooked directly to the vacuum chamber and the roughing pump backs it; that is, it keeps the pressure at the back end of the diffusion pump low enough that the diffusion pump can work effectively. When a vacuum system is in operation, the roughing pump runs continuously and backing the diffusion pump, to remove the air and other gases that the diffusion pump has extracted from the chamber.

The whole idea of the pumps is to remove about 99.999997% of the air from the coating chamber. When the vacuum is good enough for coating, an atom should be able to cross the chamber without hitting another atom. If a tungsten filament coated with aluminum becomes hot, the aluminum atoms evaporate and fly non-stop to the

Vacuum System Schematic



every surface in the chamber, including the mirror. Thus the mirror and the chamber are coated with a thin, shiny layer of aluminum.

When you plan to do some coating, you start by closing the gate valve (the valve between the chamber and the throat of the diffusion pump), opening the valve between the back of the diffusion pump and the backing pump and turning on the roughing pump. This removes air from the vacuum lines and the inside of the diffusion pump. When the pressure gets low enough, you turn on the diffusion pump and let it come up to full operation. Coating systems are sometimes left "idling" like this all the time, just so air and water vapor don't accumulate inside the pumps and their oils.

To do the coating run, you clean the mirror and mount it in the chamber. You load the tungsten filaments with aluminum and silicon monoxide, and then you lower the chamber onto the base plate. An O-ring seal and vacuum grease make the joint air tight.

Next you close the valve between the diffusion pump and the backing pump to isolate the diffusion pump from the rest of the system (which is still at atmospheric pressure) and open the roughing valve, the valve between the chamber and the roughing pump, to evacuate the air from the chamber.

It is vital that you close the backing valve to the diffusion pump *before* opening the roughing valve to the chamber because the hot oil in the diffusion pump will be overloaded or oxidized if it is exposed to atmospheric pressure — and make one terrible mess that you'll have to clean up.

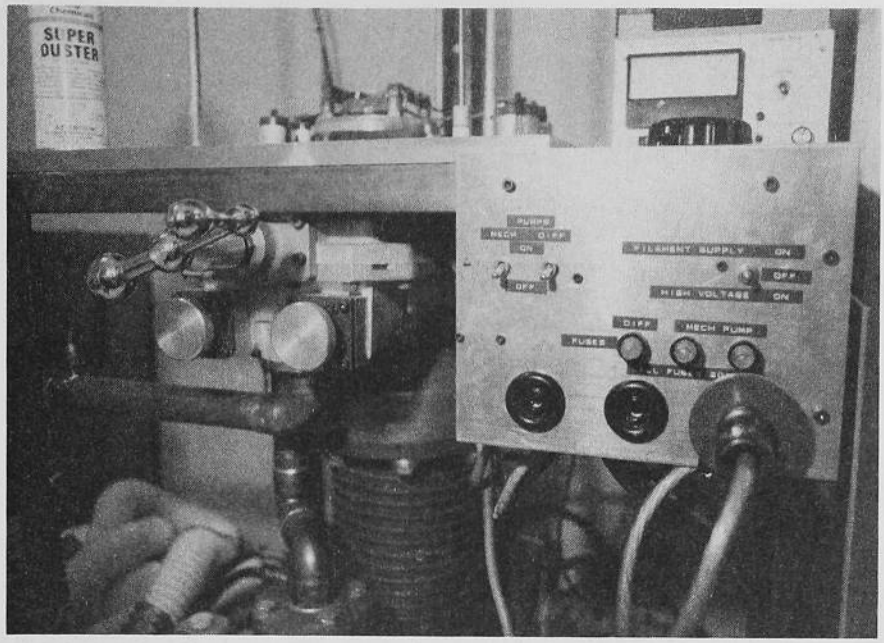
Once the roughing pump has evacuated the chamber to 0.1 Torr or less (a Torr is a unit of pressure equivalent to 1mm of mercury or $^{1}/_{760}$ of a standard atmosphere), you close the roughing valve. You then open the diffusion pump backing valve and the gate valve. This exposes the chamber to the diffusion pump, and the diffusion pump brings the chamber down to coating pressure.

When my system is running well, it takes about 15 minutes to bring the chamber from atmospheric pressure to 2×10^{-5} Torr, which is ideal for aluminizing. After a dozen coating runs, the interior of the tank gets covered with a buildup of aluminum and silicon monoxide. This buildup tends to absorb air and water vapor that outgasses slowly and prolongs the pumpdown time. It gets to the point where you have to tear down the system and clean the chamber.

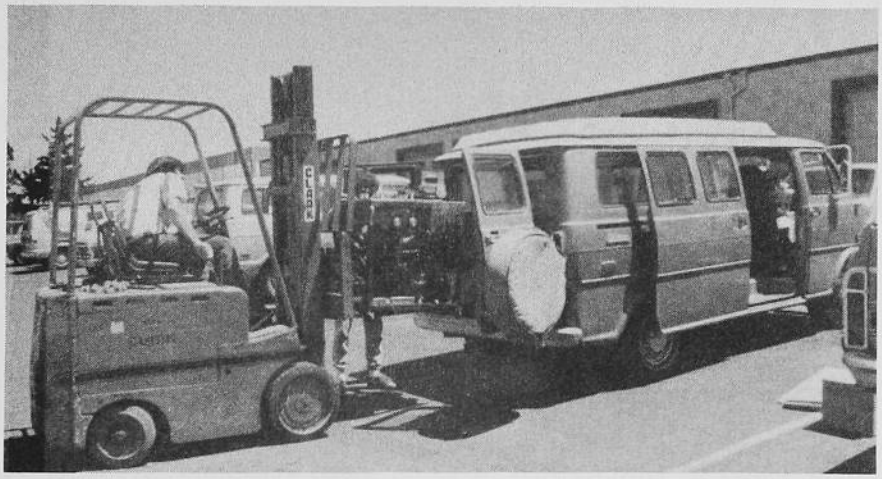
Most vacuum plants have leaks that allow air into the system, so the system cannot be static — it has to pump all the time to maintain the vacuum. All it takes is one dirty "O" ring — there are many in the average coating plant—or a scratch on the base plate and air enters the system and degrades the vacuum. The pumping speed of my system is high enough to stay ahead of the leaks and provide a vacuum that is plenty good enough for aluminizing. If I were to correct all its leaks, my system would reach a pressure of 10^{-6} Torr.

Making Mirrors

After all the vacuum stuff, aluminizing itself is actually quite sim-



An aluminizing plant requires lots of vacuum plumbing. The large "milling machine handle" operates the gate valve that exposes the chamber to the diffusion pump. The two knobs just below to the left and right of the diffusion pump valve handle are for the diffusion pump backing valve and the chamber roughing valve.



Loading the coating plant into the van for the 5,000-mile trip home. It really helps to have neighbors who own a fork lift! The disassembled plant fit perfectly in the 74 Ford camper van that the author purchased specifically for this trip.

ple. A tungsten filament is loaded with enough 99.99% pure aluminum wire to deposit an opaque film on the mirror's surface. The amount of aluminum needed varies with the distance of the filament to the mirror; the greater the distance, the more aluminum is needed and the more uniform the coating thickness.

The mirror is carefully cleaned and mounted above the filament, and the air in the bell jar is roughed out to about 0.1 Torr pressure. The mirror (and everything in the tank) is then cleaned by means of a glow discharge or ion bombardment produced by sending a high-voltage current to an electrode in the chamber. The bell jar is then evacuated to coating pressure by opening the gate valve to the diffusion pump.

The tungsten filament is heated by sending a current through it. As the filament heats, the aluminum wire melts and then flows, wetting the filament, and when full power is sent through the filament causing it to glow white hot, the aluminum evaporates. The actual aluminizing should take no longer than 30 seconds.

If the filament is not loaded properly or if too much power is applied too soon, some of the aluminum may drip off the filament, resulting in a thin coating. If power is applied too slowly, or if the vacuum is poor, the aluminum atoms may trap gas in the coating, resulting in a porous or dull coating.

However, the most important step in the aluminizing process is not the coating at all but cleaning the mirror. If there is the slightest trace of grease or dirt on the mirror's surface, an aluminum coating will not stick.

A simple test of film adhesion is the tape test. A length of Scotch tape is firmly pressed on the coated surface and then peeled away. If the mirror surface is sufficiently clean, the coating will survive this test. Otherwise the tape will lift the coating off the glass.

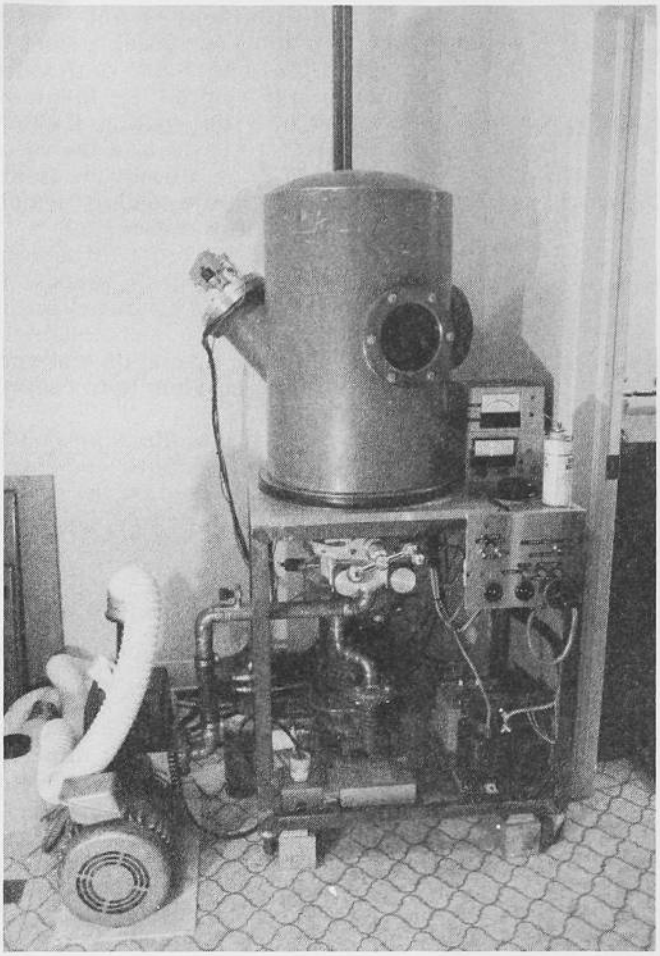
Pinholes in the coating, I am told by the pros, are a fact of life and not worth worrying about. To reduce the number of pinholes in the coating, dust and lint must be blown off the mirror prior to closing the chamber.

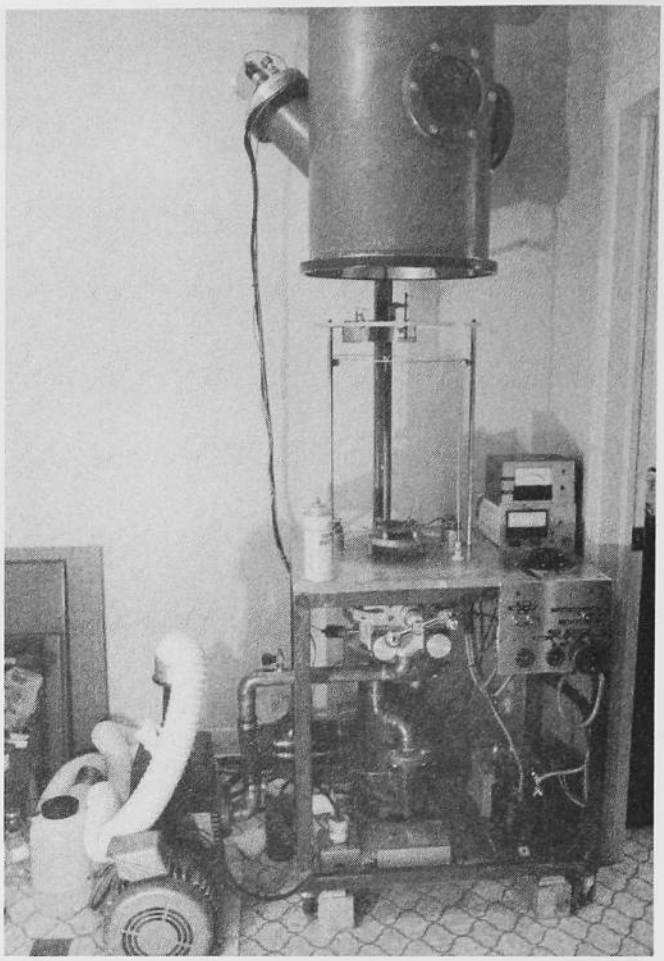
Protective Overcoats

Freshly deposited aluminum film is soft and easily scratched. To protect the film from abrasion a $^1/_2$-wave-thick overcoating is deposited over the aluminum. Most first surface mirrors are overcoated with silicon monoxide, SiO. It produces a tough overcoating that stands up well to *gentle* cleaning. Magnesium fluoride, MgF_2, is sometimes used for overcoating, but it is not as mar resistant as SiO and so is not desirable for telescope mirrors. The Hubble Space Telescope's mirrors are MgF_2 overcoated for better transmission in the ultraviolet and not for its value as an overcoat.

SiO is evaporated by putting it in a ribbon of tungsten with a dimple in it called a boat. The SiO boat is loaded by pouring granular SiO into the dimple. SiO sublimates when the boat (i.e., tungsten filament) is turned on and the SiO is heated.

To deposit the optimum overcoating, the thickness of SiO film should be monitored as it is being deposited. The high-tech way to do it is with electronic or optical monitoring devices installed in the chamber. The simplest and least expensive way to monitor an SiO overcoat is to watch it as it is deposited. When the mirror surface is observed at grazing incidence





The coating plant in my house sits in the laundry room where normal people might put a washer or dryer. When the chamber is raised, it just clears the ceiling.

during the overcoating process, a sequence of colors spreads across the surface. First a patch of yellow appears in the center and spreads across the mirror. Yellow is followed by pink, blue and then yellow again. When the whole surface turns yellow the second time the overcoat is the proper 1/2-wave thick.

To observe these colors during a coating run, I mounted a rectangular mirror just below the telescope mirror, angled so that I could see the mirror's surface at grazing incidence through the front viewing window of the chamber. A household light bulb shining through the side window provided more than enough illumination see the colors.

If the deposition rate is too quick, two or more colors will be seen at once, indicating that the thickness of the film is not uniform. In a simple system like mine in which the mirror is not rotating, a perfectly uniform coating is nearly impossible to achieve with optics as large as 16 inches unless the mirror is very far from the source. A non-uniform film causes a few percentage points' reduction in the reflectivity of the mirror, and probably isn't worth worrying about.

Stripping Old Coatings

Bare aluminum coatings can be stripped with sodium hydroxide (lye) that can be obtained in a supermarket. However, I stopped using lye after I had a bad experience with a 12.5-inch f/4 mirror that not only had its coating striped, but also lost its figure. I placed the mirror face-down in a too-strong solution; an insoluble precipitate formed on the surface completely destroying the figure. Kevin suggested that I use a "green river" solution to strip mirrors. It also works well on quartz overcoated mirrors that are difficult to strip with anything else without damaging the surface.

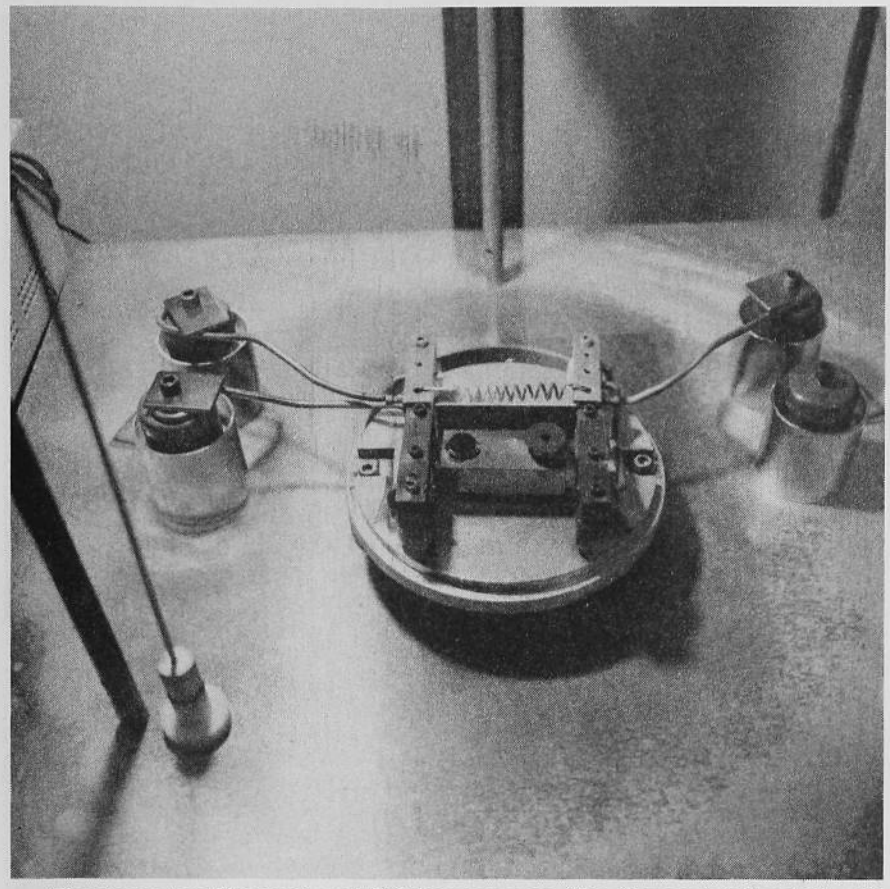
Green river is 13 grams of copper sulfate dissolved in two liters of water and mixed with 400 ml of hydrochloric acid. If you make green river solution, you should exercise care and wear proper protective gear.

To strip a coating I make a dam 1/2-inch high around the edge of the mirror with electrical tape and seal the joint as well as possible to prevent leakage. Then I simply pour the green river over the mirror and let it sit overnight. The solution does not harm the glass and if necessary can be left on the mirror as long as required.

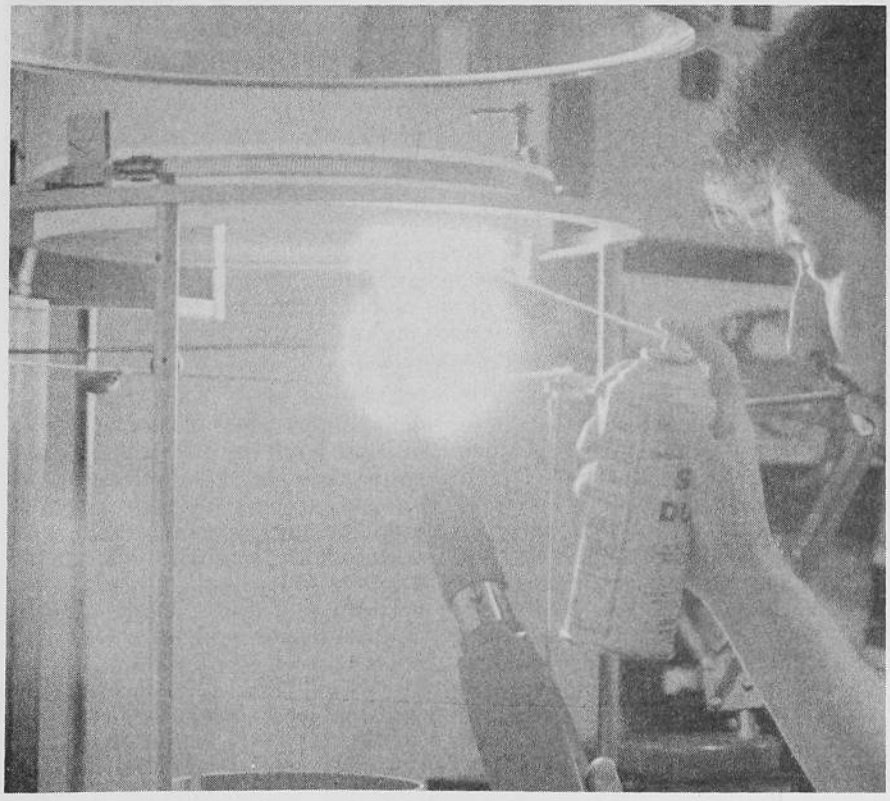
Enhanced Reflectivity Coatings

Enhanced coatings consist of a base layer of aluminum or silver overcoated with several layers of materials with varying refractive indices and thicknesses whose combination causes constructive interference of the reflected light, raising the reflectivity of the original metallic film.

Not all enhanced coatings are created equal. Some coatings enhance only a specific portion of the spectrum. The best coatings for amateur astronomers, especially for photography, are broad-band coat-



The tungsten filament and SiO boat source. The filament is loaded with enough aluminum to produce an opaque coating on the mirror. Because the filament will aluminize anything exposed to it, the sources are shielded from each other by a plate and a tubular shield that prevent most of the tank and the windows from getting coated.



The author is blowing dust off a 12.5-inch mirror with a can of compressed air. The vacuum cleaner nozzle sucks the air and the dust away from the mirror so it doesn't settle back on the surface. The 100-watt desk lamp set nearly level with the mirror surface renders any dust on the mirror's surface easily visible.

ings that enhance the entire visible portion of the spectrum. Silver-based enhanced coatings tend to tarnish even if they're overcoated because overcoatings tend to be porous.

Enhanced coatings require careful monitoring to achieve the maximum reflectivity, and this involves some very expensive and complex monitoring equipment. Furthermore, enhanced coatings tend to be expensive and must be protected from acid dew that will degrade reflectivity and cause much scattering.

Is the extra 10% light worth the added expense? It's hard to say, particularly considering that smog, acid dew and adverse atmospheric conditions may force you to recoat every several years.

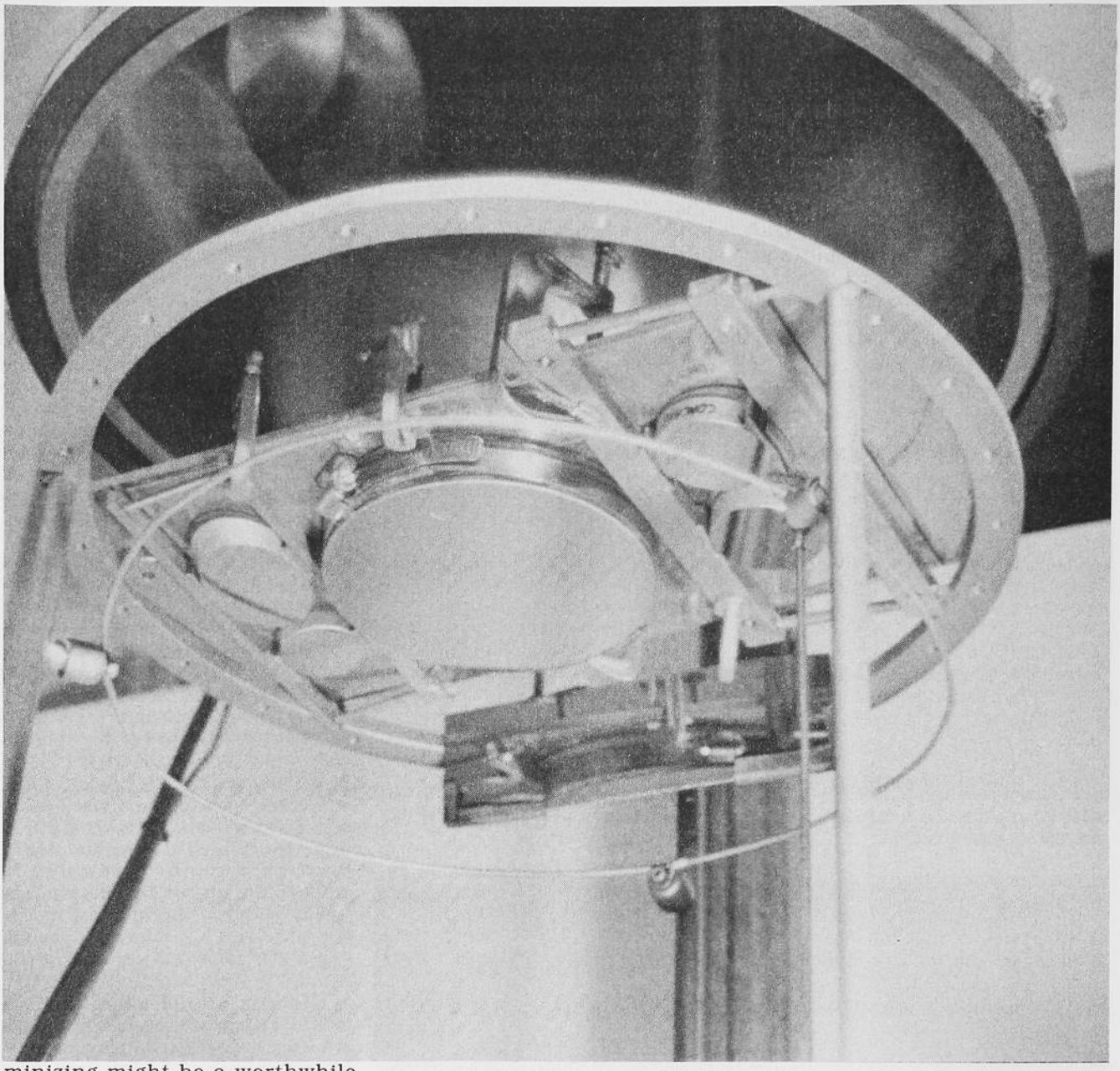
Anti-Reflection Coatings

Anti-reflection coatings for lenses are much more involved than aluminizing and overcoating. The simplest anti-reflection coating is a $^1/_4$-wave-thick layer of MgF_2. It reduces reflection off bare glass from 4% to less than 2%. Anti-reflection coatings increase light transmission and, more importantly, reduce annoying ghost images yielding a higher contrast field of view. To produce a tough anti-reflection coating, the lenses to be coated must be heated to 250° C and the deposition of the MgF_2 must be carefully monitored to achieve the proper thickness. This involves installing heaters in the chamber and a monitoring system since the anti-reflection coating cannot be easily monitored visually.

Modern anti-reflection coatings found in the best eyepieces and camera lenses are very complex, consisting of four layers of substances with different refractive indices that reduce stray reflections to 0.25% or less. All things considered, even simple anti-reflection coatings are quite involved and are perhaps best left to the professionals.

Who Needs a Coating Plant?

Certainly not everybody. While most TMs would agree that alu-



A rather ambitious run of five mirrors at once! The center 6-inch mirror is surrounded by three Cassegrain secondaries and a diagonal mirror. Note the homemade clamps with vacuum grade rubber to hold the smaller optics in place. The mirror clamps and the 6-inch mirror are attached to an aluminum plate with C-clamps for loading into the chamber.

minizing might be a worthwhile project for group of mirror makers, most TMs reading this article will probably wonder why anyone would spend thousands of dollars on a coating plant when one can send off the few optics one is likely to make to be coated for as little as $3 per inch of aperture?

I have to admit that my coating plant has been idle 99.9% of the three years I have had it. But practical individuals are seldom members of the obsessive, Tele-scope Nut fraternity. I am starting to gather components for another, much larger chamber that can handle 30-inch mirrors (yes, this is my dream scope) for the simple reason that such monster mirrors would be difficult to ship to a commercial coater. The biggest hurdle will be to find a vacuum chamber 40 inches in diameter that can be used in a horizontal position because suspending a big mirror face down is, to say the least, difficult.

For me, aluminizing has added a new dimension to telescope making. Like optical work, aluminizing has its pleasures and frustrations. It's fun watching the glow discharge ionize the air in the chamber so it glows an eery blue-green. It's fascinating to watch the aluminum condense on polished glass and form a mirror. With my basic plant, and some practice, I have found aluminizing to be quite easy. I recommend aluminizing for groups with enthusiastic members. Now that I have my own coating plant, I am proud to say I am making mirrors, not just mirror holders.

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Sending Your Mirror off to be Aluminized: Some Do's and Don't's

When you send your weathered optics off to be aluminized you have a right to expect a bright and spotless coating when the optics are returned to you. This is easily achieved if you take some simple precautions as you care for the original coating and when you pack the mirror for its trip to the coater.

Precautions for Mirror Makers

For an aluminum film to appear bright and scatter free, you must be careful to remove all pits during the grinding and polishing stages. If you don't, you risk being surprised by a hazy aluminum coating (see "Coatings, Cosmetics and Guarantees"). Large pits on a polished surface are indicative of too little time in grinding, particularly during the coarser stages.

During polishing, a residue from polishing compound can build up around the edge of the mirror. This caked-on material can make the already tedious job of cleaning the mirror for aluminizing more difficult. You should scrub the sides and back of the mirror with a scrubbing pad to remove any traces of polishing compound or pitch.

During polishing, you should not allow water marks to form because these may be difficult or impossible to remove without damaging the surface. When polishing compound dries on the mirror during cold pressing, water marks often result. Wrap a wet cloth around the edge of the mirror to prevent the water from evaporating.

You should also chamfer the edges of the mirror with a fine grinding stone. If there are any chips, smooth the jagged edges because the mirror will be easier to clean and less prone to further chipping during handling.

It has recently become popular to mount mirrors with RTV cement because it is easy to mount a mirror this way and because it does not strain the optics. Remove the RTV by scraping with a single-edged razor and scrubbing away the residue. The cement must be completely removed from the mirror because RTV may outgas and make it difficult to achieve the high vacuum required for a good coating.

Packing Precautions

Do not ship the mirror in a plastic bag or wrap it with a Saran Wrap-type plastic wrap because the mirror surface may stain. Instead, lay the mirror face down on some soft paper toweling and wrap it tightly with newspaper and masking tape. Place the wrapped mirror in a large cardboard box with plenty of packing material all around it, especially at the edge. Thick foam around the edges of the mirror will help it survive shocks. While a wooden box may stand up better to the gorillas in the post office, it is not really necessary. And if you *must* use a wooden box, don't use a dozen wood screws with different heads to keep the lid on! Furthermore, don't varnish the box be-cause the varnish will outgas and may stain the mirror.

The mirror should never be shipped in its cell. The cell is of no use to the coater and the mirror may be damaged if it is jarred loose and starts rattling around during transit. The extra weight of the cell also makes shipping more expensive.

When to Recoat

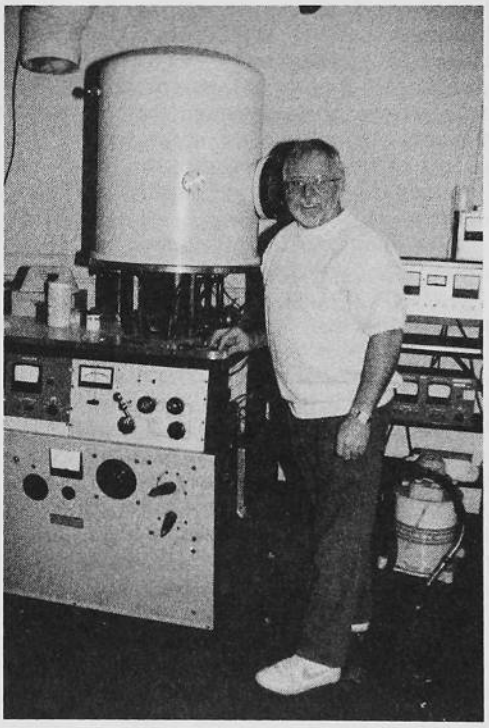
The first-surface mirrors in a reflecting telescope are directly exposed to the elements and they will weather quickly if not taken care of properly. If you allow condensation to form on the mirror, the life of the coating will be reduced by acids in the dew. Proper storage of the telescope and covering the optics will help prevent excessive weathering.

Gently cleaning the optics on a regular basis helps prolong their life since a dirty mirror will dew over faster than a clean one. If you allow the coating to deteriorate too much, the glass itself may become stained. A mirror should be recoated before the aluminum film on it looks really worn. A weathered coating scatters light, causing a diffuse halo around bright objects and stars.

Special Handling for Canadians

When you ship a mirror across the border, do not use United Parcel Service because of customs and duty problems as well as brokerage fees. Use parcel post and pack the mirror well to resist shock. You should also clear your mirror through customs before shipping it out, because if you don't you may be taxed on the mirror's insured value when it is shipped back to you.

Keeping these simple precautions in mind when preparing your mirror for aluminizing will help avoid problems and make the aluminizing painless for both you and the coater.



George Montierth of Morvac coats mirrors for amateur astronomers the world over and he provides coatings for many telescope manufacturers.

George Montierth
Morvac Optical Coating
2300 Walnut #B
Signal Hill, CA 90806

Coatings, Cosmetics and Guarantees

After a telescope maker has slaved for months to produce a surface accurate to a few millionths of an inch, he or she carefully packs the precious mirror and ships it off to be aluminized. A few weeks later the mirror returns with a shiny surface but to the maker's horror the surface now appears dotted with pits and marred by scratches. In a fit of anger, the unhappy TM chastises the coater for ruining the mirror.

This scenario is not fiction; it happens all too often.

Unfortunately, the TM is usually at fault.

Here's why: During rough grinding, the mirror maker uses coarse abrasives to grind a concave surface into a flat Pyrex blank in a reasonable length of time. More often than not, he or she fails to spend enough time fine grinding the mirror. Large pits that are hard to see by the untrained eye remain through grinding and escape notice through the course of polishing and figuring.

Aluminizing greatly enhances the visibility of pits and scratches, and their sudden visibility catches the mirror maker off guard. Pinholes in the coating are another fact of life that should not cause undue concern. Most observers won't see the difference between a perfectly clean surface and one suffering from a few imperfections — unless they are truly severe — and will be content with the performance of the mirror. Likewise, a dozen pinholes across a mirror is considered excellent and will have no practical effect on performance.

But if the mirror maker is a perfectionist, all pits and scratches must go. A trick for spotting these imperfections that I learned during my apprenticeship as an optician is to spray paint the sides and the back of the optic with clear plastic lacquer and then with flat black paint (the initial plastic coat makes the paint easier to strip). With a bright inspection lamp and a clear bulb, a 6x to 10x magnifier, and a lot of patience, the TM should be able to produce a first-class optical surface. The black background cuts the glare that hides pits and scratches from view. Keep a squeeze bottle filled with alcohol and a box of tissue close by to wipe the surface clean of fingerprints and dirt. Sometimes suspected pits or scratches simply wipe away.

A well-figured mirror is often afflicted with fine scratches or "sleeks" because of the short polishing spells and imperfect contact between pitch and glass. Sleeks are hard to avoid while figuring so don't worry about them.

However, remember to strip the paint completely from the mirror before you send it off to the coater because the paint may outgas in the chamber and make it difficult to achieve a good vacuum.

Misunderstandings over cosmetic defects in mirrors cause several professional optical houses that I know of to shy away from having anything to do with TMs and their optics. Being both a TM and a professional optician, I have heard both sides of the story. Most TMs don't realize how valuable coating plant time is in a commercial outfit. A 12.5-inch mirror can tie up a plant just as long as a dozen smaller mirrors — and the smaller mirrors pay more! Because of this, the mirror may be rushed through the process and an inferior coating may be deposited.

Unfortunately, commercial coaters fails to realize that what they consider cheap for a coating job appears as a large expense to the average amateur. Even though the professional optical shops may charge several times as much as the coaters that cater to the TM market, don't expect too much. For example, professional coaters probably won't recoat the mirror if there is a cosmetic blemish in the film; they probably think they've done you a big favor just for doing the job!

Some mirror makers may be shocked to learn that although coating houses usually guarantee their coatings, if the mirror is broken coaterd do not accept liability for the damage. Even if they replace the mirror because they feel guilty, they are under no obligation to do so. The reason is that it is just not feasible for coaters to insure themselves against possible damage to a $2,000 piece of glass when they are depositing a $40 film of aluminum. Before you send your mirror off to be coated, make sure you know what to expect if disaster strikes!

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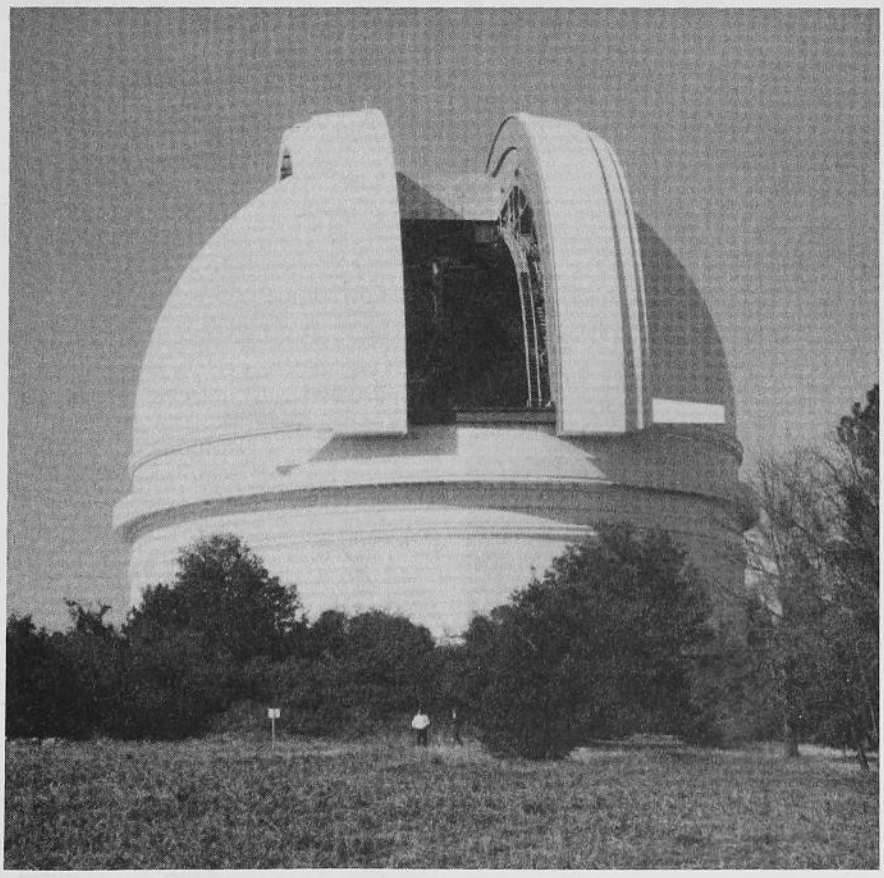
Aluminizing the Mirror of the 200-Inch Hale Telescope

Full Moon is a good time for aluminizing. Of the five telescopes currently in use at the Palomar Observatory, three, the 18-inch Schmidt, the 48-inch Oschin Schmidt, and the 20-inch Cassegrain, allow five- to ten-day Full Moon times when the schedule calls for no observing.

But the 200-inch Hale and 60-inch telescopes are scheduled for observing 363 days per year — they're closed only on Christmas Eve and Christmas Day. The established procedure at Palomar is to allot engineering time on a regular schedule that will have minimum impact on observing programs for routine work like washing or aluminizing mirrors. This story describes a typical engineering run in which we remove the 200-inch mirror from the telescope, remove the old aluminum coat, and apply a new coat of aluminum.



The dome of the 200-inch Hale Telescope.

Preparing to Aluminize

We store the aluminizing chamber for the Hale telescope on the observing floor of the dome to the northwest of the telescope. The chamber sits on a cart which can raise or lower it about six feet. To put the mirror in the chamber, we remove the upper portion of the chamber and roll the base of the chamber and the cart under the telescope. When we remove the 200-inch mirror, we lower it directly into the base of the chamber.

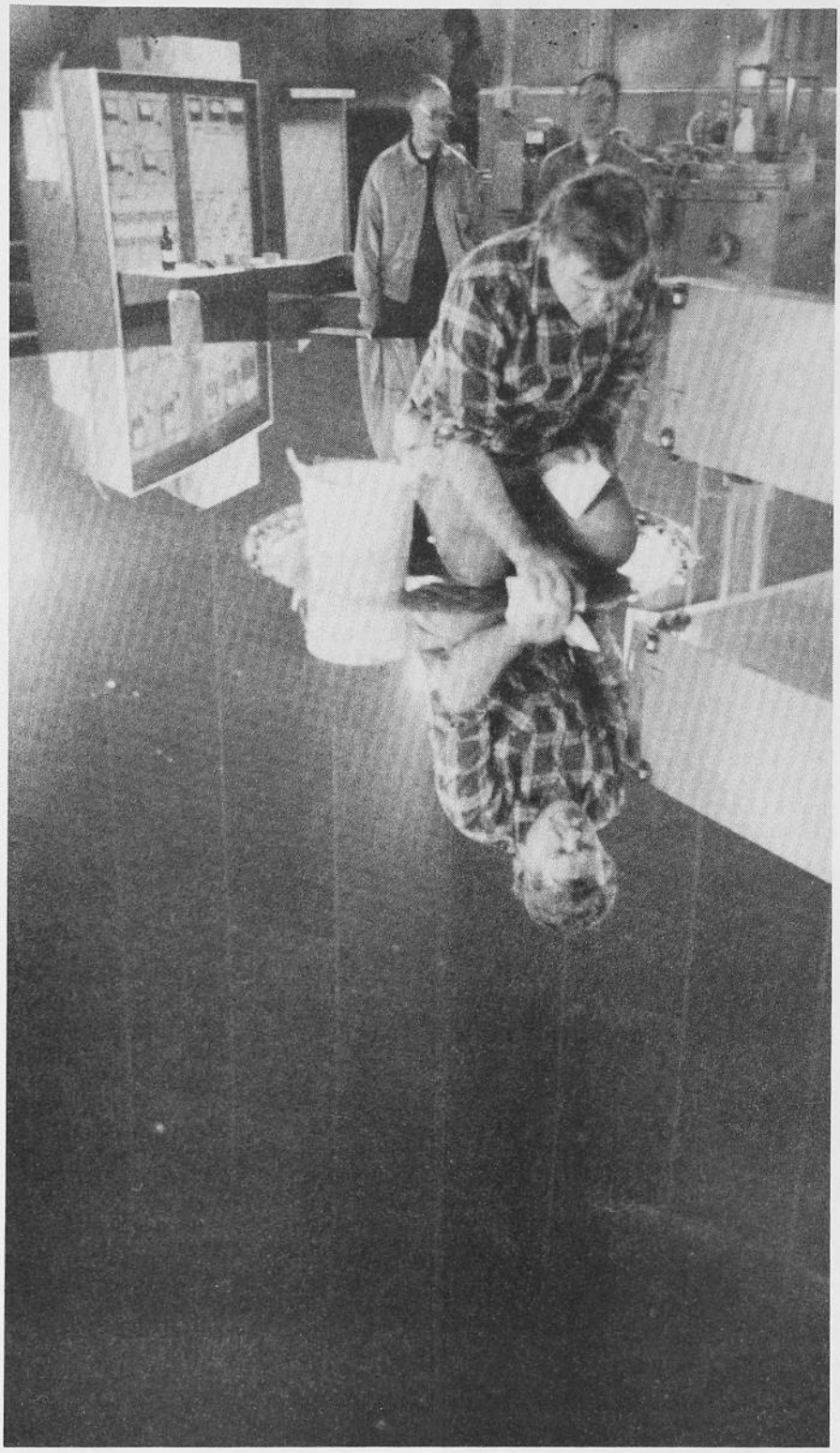
Preparing the chamber begins when we remove the upper body of the chamber and set it aside on the observing floor. We'll evaporate aluminum from 360 filaments located in the top of the chamber. Each filament and its associated wiring and control circuitry must be checked for continuity and short circuits.

After the electrical circuits have been checked and readied, five measured lengths of pure aluminum wire are suspended from each filament. We take great care to prevent touching the aluminum with the bare hands, because body oils slow the evacuation of the chamber during the pump down period. We next inspect the roughing pumps, diffusing pumps, blower pumps, cold traps, associated plumbing, controls and measuring device to insure proper operation.

All the various chemicals, tools and materials are assembled on the observing floor, and a preparatory meeting is held. We assign duties for the engineering run, outline procedures for specific tasks, and review all safety procedures.

Day One

7:00 a.m.: The crew meets in the 200-inch data room for a final



The author touches up after the first wash.

review of the task list. Throughout the engineering run we keep the dome closed to prevent dust accumulation and, of course, to prevent sunlight from striking the optics. Imagine the damage that could result should sunlight reflecting off the 200-inch mirror be focused on some portion of the dome or telescope! So the dome lights are turned on and several tasks are begun simultaneously.

The electronics crew removes observing equipment used the night before. Meanwhile, another group of workers secures the telescope to prevent it from moving after the 30 tons of mirror and mirror cell have been removed from the tube assembly. At the north horseshoe bearing, a large A-frame ties the right ascension horseshoe to the telescope base frame. The declination axis is secured with two beams, so that the telescope tube is tied solidly to the yoke arms.

The coudé pedestal, which normally is attached to the mirror cell through the perforated primary, is strapped so that it can hang suspended from the telescope tube after the mirror has been removed. The secondary mirrors are placed in their stowed positions and the counterweights that are used for telescope balance are placed in their bottom-most positions.

As the work proceeds, supervisors inspect completed tasks and review written procedures/checklists to insure that nothing gets forgotten.

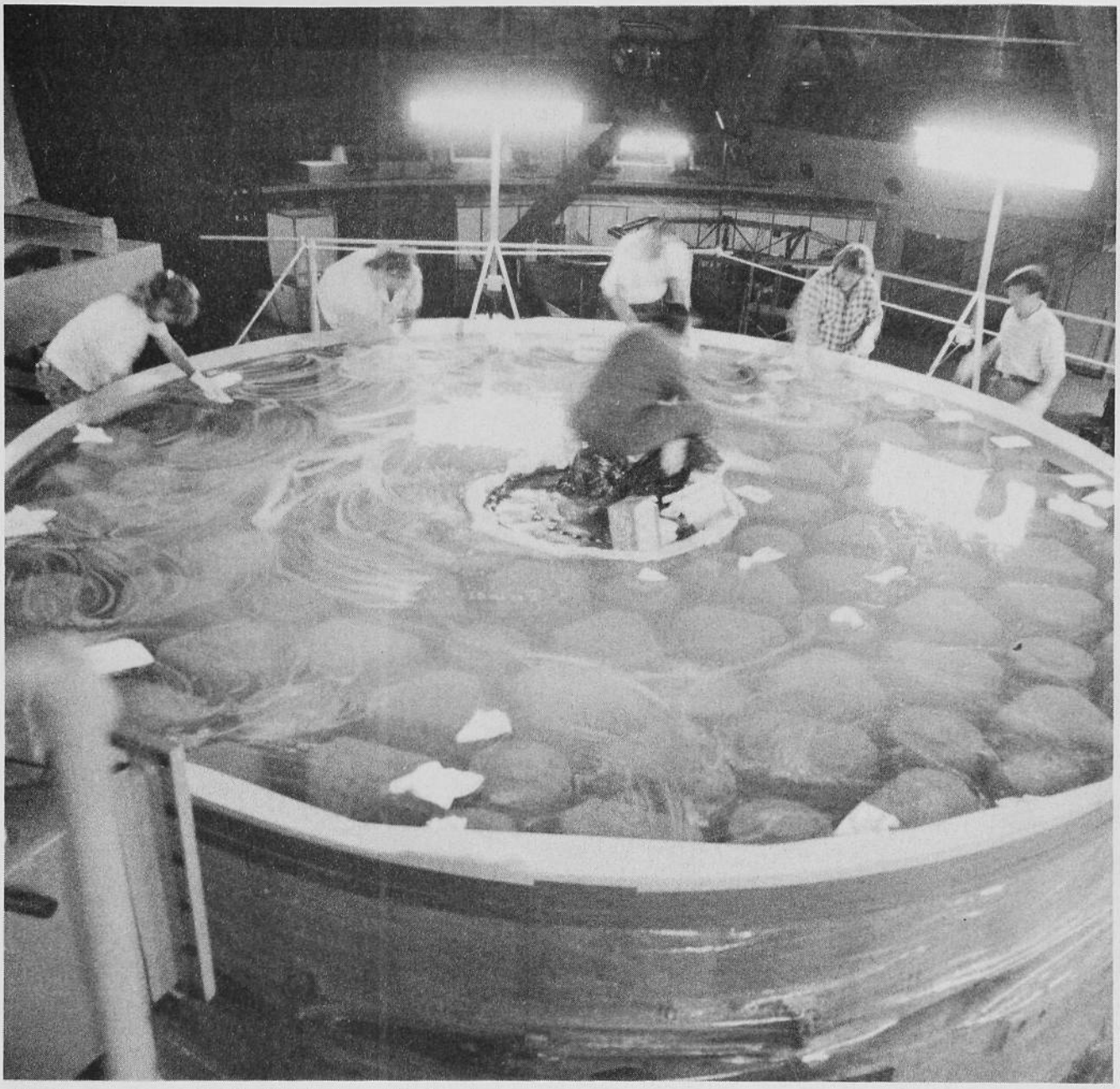
9:00 a.m.: A specially built cradle is rolled out under the telescope and onto the central five-ton floor lift. The lift is raised until the cradle makes full contact with the Cassegrain instrument cage. Bolts are removed from the perimeter of the Cassegrain cage and the 2300-pound cage is lowered away from the telescope, leaving the mirror cell bare.

9:30 a.m.: Workmen enter through the bottom of the 40-inch diameter Cassegrain hole to remove the bolts that secure the coudé pedestals. One man works above the bolt circle with an electric impact wrench and a second man assists him from below. Eye and ear protection are an absolute necessity on this job because the 14-foot-long metal tube amplifies the staccato of the impact wrench and dust flies about from the vibration.

10:15 a.m.: With all electrical cables detached and all mechanical fixtures removed from the cell, the interior of the cell is dusted and wiped down with acetone. Thorough cleaning here means less outgassing during pumpdown. We take care during this step because within the cell are the 36 back supports which carry the 29,000-pound 200-inch mirror.

11:00 a.m.: The platform that holds the base of the aluminizing chamber is rolled out from its storage location. The platform rolls on steel track set into the dome floor. When the platform is under the telescope, we elevate it until it contacts the mirror cell.

Eight angled knee braces secure the mirror and cell to the telescope framework. After the platform is in contact with the cell, we remove four 1-inch and 1.5-inch nuts from each of the eight knees. The cell



Its aluminum gone, the big disk is cleaned by hand.

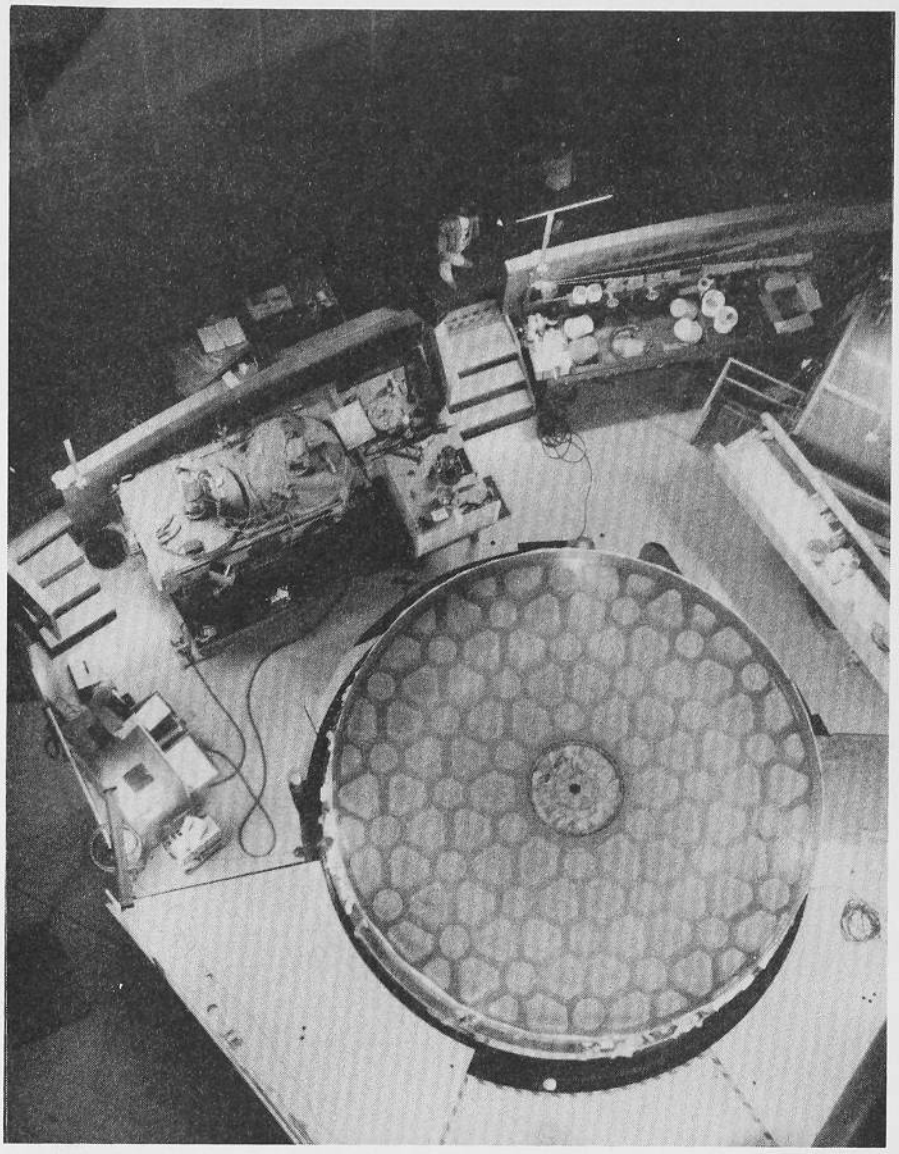
and mirror are now free to be lowered (never say "dropped") out of the telescope. The mirror, still in its cell as it will be throughout the entire process, is rolled back to the aluminizing area.

For the upper portion of the chamber to fit over the mirror and its cell, we next remove the knees from the cell. Next, we set up scaffolds around the cell and mirror to provide access to the entire perimeter of the glass. To insure adequate illumination for inspection, we install portable lighting on the scaffolds.

Noon, the wash: The surface of the mirror is inspected to determine if there is any material on the mirror which may need special attention in cleaning. There is always lots of dust, of course, but we're mainly on the lookout for small oil spots from the light-weight oil used in the declination worm and worm gear reservoir that is above and to the west of the mirror, water spots that are caused by condensation dripping off the dome or telescope, and contaminants like pollen, ash from distant fires, etc. Oil spots are removed by using solvents before preceding with soap wash.

When we wash the mirror, it is necessary to prevent water from getting into the cell area below the mirror. The delicate support system for the mirror is located under the mirror, and water, if it were trapped below in the cell, would not only cause rusting, bearing damage, and so on, but would also seriously lengthen the time it takes to achieve a good vacuum because the water, along with the air, must be evacuated by the pumps.

To prevent spillage, we tape a Mylar dam around the perimeter of the mirror. The dam protrudes about 4 inches above the surface. An additional skirt protects the cell below the mirror. In the central perforation of the mirror we install a pan with a O-ring that seals to the glass. The flange that the coudé pedestal mounts to supports the pan. The pan has a handle in its



Looking down on the 200-inch from the upper catwalk.

center that, after installation, is replaced by a drain assembly that passes liquids through the mirror and cell below.

When the dam is in place, crew members begin applying soap and distilled water solution to the surface from buckets using sponges. We do not use tap water for fear of contaminating the sponges with particles which might later cause scratches. The surface is completely wetted and then kept wet for a period of 10 to 15 minutes so that the soap can lift and float away as much dust as possible. It is important to keep the mirror constantly wet in order to prevent drying marks from forming. The mirror is then rinsed using filtered tap water at low pressure through a garden hose with its metal nipple cut off for about 10 minutes.

When the rinse is complete, one worker stands in the center of the mirror and the other members of the wash team stand around the perimeter. They begin patting the surface with sponges soaked with Orvus soap and distilled water. The procedure is to pat the surface three or four times, turn the sponge over, pat 3 to 4 times again, and then rinse the sponge in the soap bucket. The idea behind this patting procedure is to dislodge and lift off any debris that might scratch the surface. If we rubbed instead of patted, of course, the motion might carry the debris across the polished surface and scratch it.

After the entire surface has been patted and washed, we rinse the mirror for 10 to 15 minutes and then wash again. If we're simply washing the mirror and not aluminizing it, we would wash it two or three more times, give it one final rinse with distilled water, and then dry the surface by pulling chamois skins across it. A mirror wash can be completed during the daytime hours, and no observing time is lost.

Because we're going to aluminize the mirror this time, and because all the dirt will be removed with the aluminum coating, only one more wash need be done. Some wiping motion can be done after the initial wash, but workers are careful to apply very little pressure to the sponge.

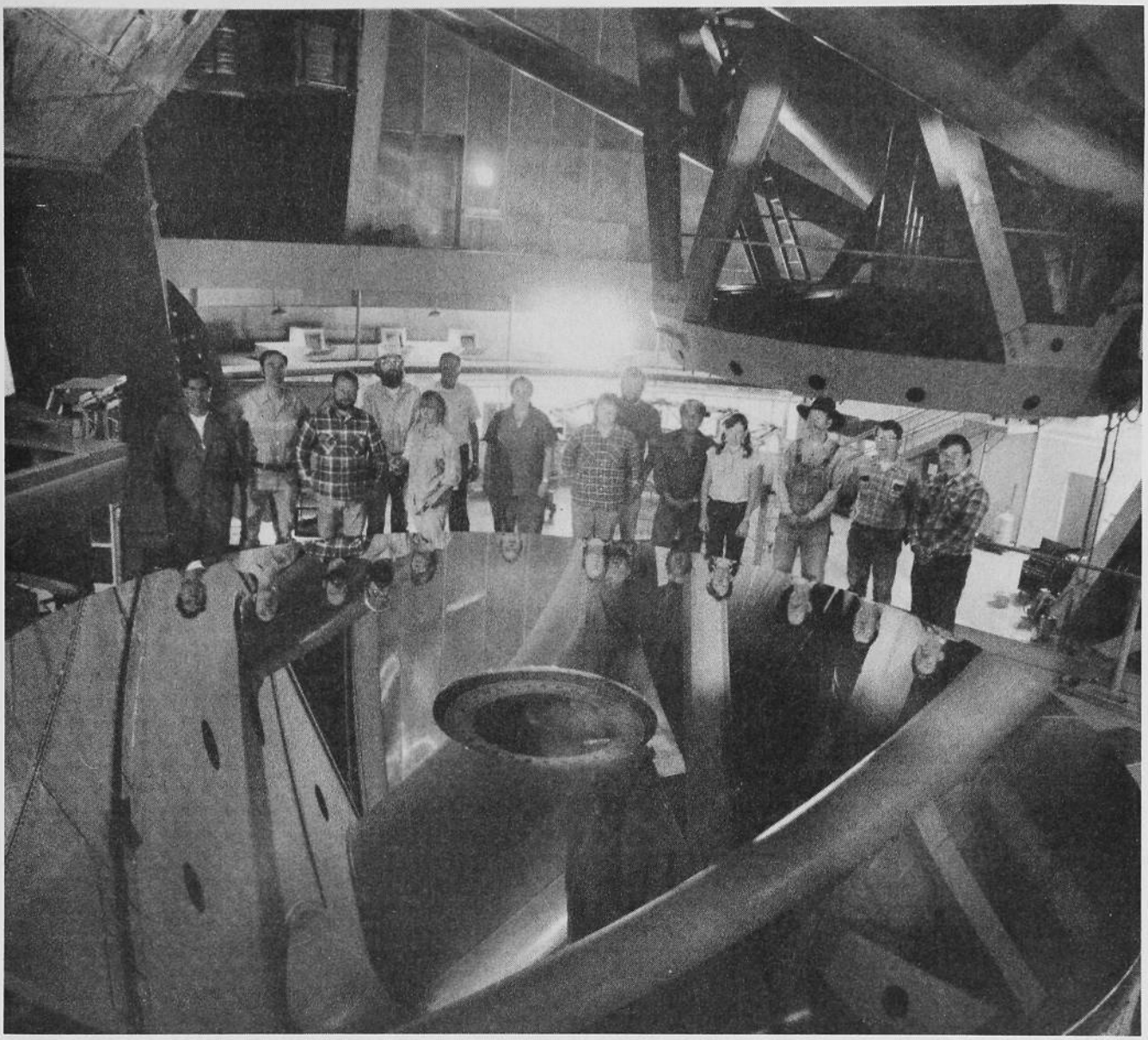
After a hose rinse, the wash team dons respirators and protective clothing to protect them from the acids and caustic chemicals that we use to remove the aluminum from the glass. Fans are set up to draw fumes from the work area and exhaust them outside.

2:00 p.m., the acid wash: We now mix a solution called "green river" a combination of 1 quart hydro-chloric acid, 2 quarts water, and 1 ounce of $CuSO_4$. (The $CuSO_4$ turns the acid solution green.) This solution is carefully poured from plastic buckets over the surface from the perimeter. To slow the flow of acid from the surface and allow more time for the chemical to dissolve the aluminum, we place a dam of disposable lint-free paper lab towels about half way to the center and place a second dam around the perforation.

After a few minutes, workers begin wiping the surface with lab towels to aid in the removal of the aluminum. This is a dangerous time in the aluminizing process, because the wash-team workers must stretch out over the glass to reach the entire surface. The worker in the center pan must squat because he cannot kneel in the acid that is flowing to the drain beneath him.

Workers must furthermore be careful that their fume masks and safety goggles are well secured — if their protective gear falls off and hit the glass surface, damage could result. After five to ten minutes the honeycomb structure of the Pyrex glass can be seen through the aluminum, and the mirror begins its metamorphosis from mirror to Pyrex jewel. After 20 minutes of the acid wash, if there is no longer any evidence of aluminum, we remove the lab towels and begin a ten-minute hose rinse.

The next step is to apply a caustic solution to the surface. The caustic removes any minute aluminum particles which may still adhere to the surface. This solution is 1 part KOH mixed with 25 parts of water. Again, we place dams on the surface, and after applying the solution, agitate it gently with lab towels. After two or three minutes,



Their job completed, the aluminized poses behind the 200-inch mirror.

we spread $CaCO_3$ powder over the surface and then, using lab towels, mix the powder with the KOH solution. We wipe this solution over the surface for 5 to 10 minutes. When it starts to dry out, we rinse the surface with hose water.

After a 15 minute rinse, we pour a solution of nitric acid, (one part acid to 2 parts water) over the surface. Once again, we put dams in place and agitate the solution. We don't let the nitric acid stay on the surface more than five minutes to insure that there is no possibility for the acid to etch the glass. Next comes a 30-minute rinse, and then all the protective clothing can be removed and returned for washing and storage.

During the entire cleaning procedure, no part of the surface can be allowed to dry. If any portion of the surface dries, there will be some type of drying mark which means returning to the acid wash. If all has gone well, we can remove the Mylar dam. Distilled water, about 20 gallons, is now poured over the glass. Because some water inevitably flows over the rim, workmen stand by to mop up any spills. The skirt which has protected the mirror cell is now removed.

3:30 p.m., drying and final wipedown: The next stage is drying the mirror and leaving it both clean and dry. The wash team puts on disposable cotton gloves and we dry the mirror surface with lint-free disposable lab towels. To prevent scratches, the towels are changed frequently.

Once the surface has been dried, we immediately wipe the surface with alcohol. A lab towel is held in one hand and a squeeze bottle is used to apply a small amount of alcohol to the towel. The towel is then wiped across the surface in one pass and discarded. After about 20 minutes of wiping with alcohol, we begin "black breath" testing.

"Black breath" testing is a way of checking that the glass is chemically clean. Breathing onto a clean surface should produce a thin, even layer of condensation which will be visible for a few seconds against the reflection a distant light source. The fluorescent work lights in the dome are great for this type of testing. During the few seconds before the

condensation evaporates, wipe marks and other surface defects will be apparent. When the black breath test shows a smooth even surface over the entire surface of the mirror, we stop wiping. The alcohol bath can take an hour or more. The alcohol not only cleans the surface but also neutralizes electrical charges which would attract dust particles.

5:00 p.m.: We inspect the mirror again, this time checking the surface cracks left over from the annealing process. (During the annealing process when the mirror was made, a power failure caused the annealing oven to cool too rapidly, and a support sagged from the oven onto the cooling disk.) The resulting crack is inspected at each aluminizing to make sure that it is not expanding.

5:30 p.m.: We leave the mirror to the watchful care of the 200-inch night assistant.

Day Two

7:00 a.m.: Over coffee we review the schedule for the coming day.

7:30 a.m.: The crane operator enters the prime focus elevator and pushes the up button. As the elevator climbs the curved track on the interior of the dome, a spur gear counts the teeth of a curved rack gear, mechanically transferring the position to a worm gear, which, along with the worm gear it drives, levels the platform on its journey to the top of the dome.

Stepping out of the elevator, the crane operator climbs onto a catwalk 75 feet above the observing floor and walks its length to the overhead Cleveland bridge crane. To his right and far below is the 200-inch Pyrex disk. From this vantage point he can easily see the classic donut pattern of the mirror's paraboloidal figure when the mirror is illuminated by overhead lights. After powering up the crane's electric motors, he lowers the massive hook to the upper portion of the aluminizing chamber. The thrumming of the motor driving the 4'-diameter drum, as it sends the cables of the lift hook downward, drowns out speech inside the dome.

Below, a supervisor rotates the dome to a position that will put the crane over the chamber. Using a two-way radio, he gives instructions to the crane operator, and together they guide the 50-ton hook downward and into the lifting eye of the chamber. When the lifting eye and the cables that attach it to the chamber grow taut, the crane abruptly stops.

At the mirror, a crew has repeated the alcohol wipe of the mirror to insure that no dust remains. They finish and then remove the drain at the center of the mirror. The center pan meticulously cleaned and the lifting handle, with its airtight seal, is installed. The mirror is ready.

Last-minute checks also ready the chamber. The O-rings are lubricated with vacuum grease and the seals are cleaned. Tension among the workers climbs as the four guide poles are lifted into place alongside the mirror. The poles will guide the upper chamber when the crane lowers it over the 200-inch mirror.

Standing on the observing floor with the dome drive control paddle in hand, the supervisor signals the crane operator and the chamber lifts off with the loud drone of the crane. Like some sort of cylindrical fling saucer, it climbs upwards into the dome. The supervisor gives the order to stop when the chamber is at the same height as the mirror and 20 feet to the south side. Moving to the interior catwalk of the dome, at the same level as the mirror, the supervisor sizes up the position of the chamber, the dome and the crane. He gives an order and the chamber rises until it is about 8 feet above the mirror but still to the side.

The supervisor, standing on the catwalk of the moving dome, must keep in mind his frame of reference. As he moves the dome, he feels that the observing floor is moving and not the dome, the crane, and himself. As he positions the chamber directly above the mirror all the possible nightmare scenarios flash through his head — the 200-inch mirror is never more vulnerable to total destruction than it is now.

The workers in the dome are silent as the supervisor doublechecks positions. He calls to the workers below to take up positions at each guidepost and then tells the crane operator to lower the chamber. When the chamber is 6 inches above the guide posts, he calls for a stop. Positions are checked and rechecked. Again the down command, and again the stop command.

The chamber now swings less than an inch above the guide-posts and a couple feet above the mirror. The workmen stationed at each post are consulted, minor adjustment are made and the down command is given. Almost immediately stop is called — the chamber has just begun to slip over the guideposts. The posts are all checked and the down command issued. The chamber lowers toward its base below. As the chamber slips over the mirror, the air begins to rush out of the vacuum port near the supervisor. As the large O-ring of the chamber that fits around the mirror's perimeter approaches the lip of the mirror, the stop command is given.

The supervisor gives the order to lift the base of the chamber. The base slowly climbs upward to mate with the chamber. Once together, the O-ring makes contact between the two assemblies and forms a vacuum-tight seal.

Inside the chamber, another large O-ring separates the glass into fine and intermediate vacuum areas. A rubber collar below the O-ring seal separates the intermediate from the rough vacuum area at the base of the chamber. The chamber has engulfed the mirror and cell. Pumpdown is ready to begin.

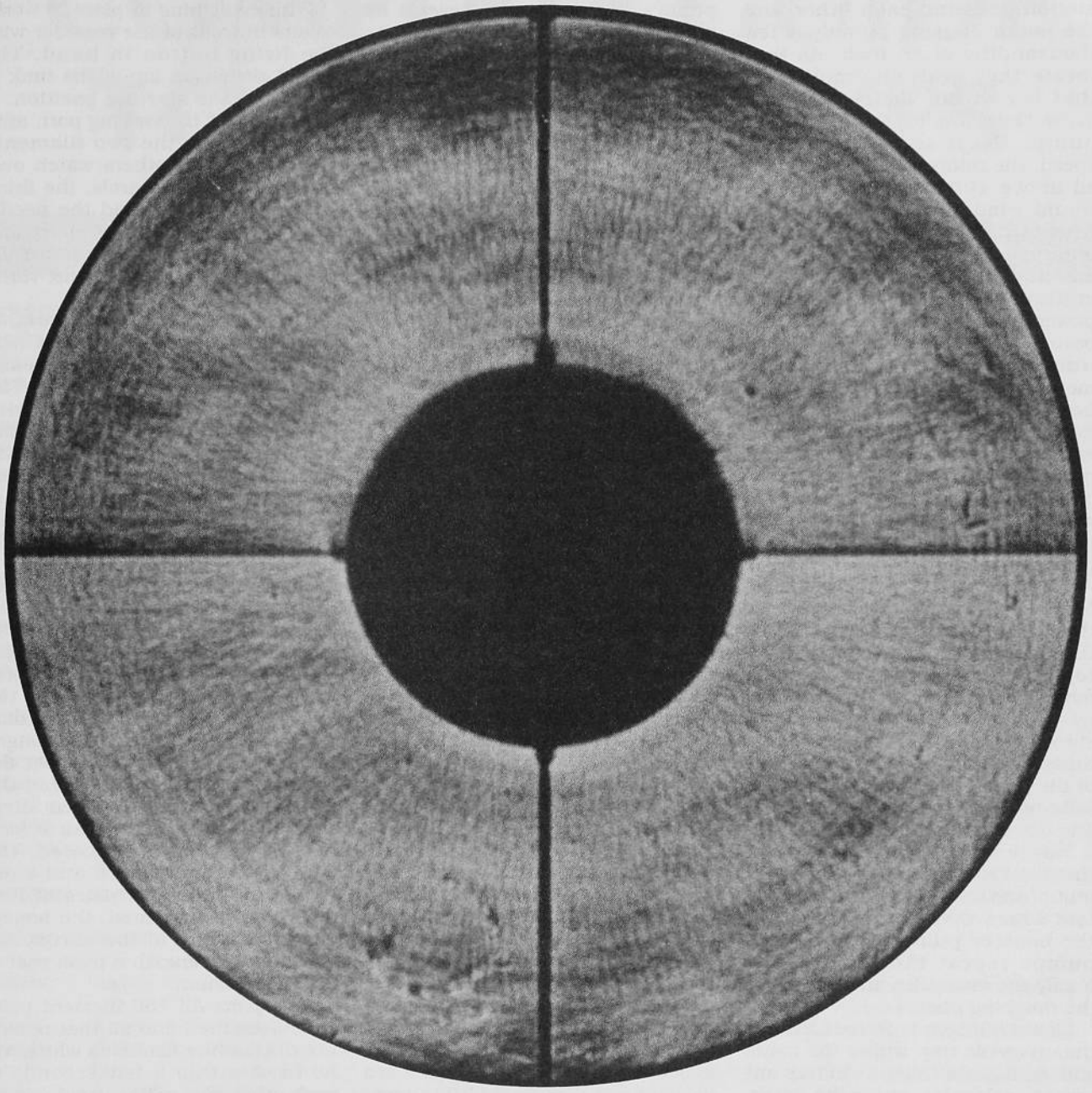
9:30 a.m., pumpdown: The chamber is lowered until it lines up with the port on the vacuum system and then pushed into contact and the port secured to the chamber. Immediately, the three roughing pumps in the system are one by one turned on and the ballasting process begins. Ballasting removes moisture from the vacuum oil in the pumps. The pumps expel clouds of the white smoke to the exterior of the dome.

Workers hook coolant and drain lines to the diffusion pumps on the outside of the aluminizing chamber, while others hook up vacuum sensors. Flanges are double-checked and fittings tested. Coolant water begins to flow; a gurgle from the drain below announces the water's arrival.

10:00 a.m.: After the roughing pumps have warmed up and reached an internal pressure of about 50 microns, a switch is thrown on the control console activating the pneumatically controlled main roughing valve. Two pumps inhale air from the chamber through the lower port. Again clouds of vapor erupt from the vents outside the dome.

The pressure falls rapidly. Above the noise of the pumps, workers hear the sound of air whistling through the lower port. Within minutes the sound subsides, and the atmosphere within the tank drops toward a pressure of 1000 microns (1 millimeter of mercury).

Meanwhile, the third roughing pump begins backing the two diffu-



This focogram shows the figure of the 200-inch primary. Note the annealing cracks near the right side and at the top.

sion pumps. Mechanical pumps do best in moderate vacuums; when pressure falls too far, they stop working effectively. Diffusion pumps are just the opposite: they pump best in a near vacuum. When the roughing pump has evacuated the diffusion pumps to a pressure of 100 microns (i.e., 0.1 millimeters of mercury), heaters are turned on that will heat the oil inside the pump.

Coolant water is turned on and begins its course through the coils on the outside of the diffusion pumps. Flow is checked and adjusted to the proper rate. Temperature sensors begin responding to the rising heat. Refrigeration units are turned on and begin cooling the cold traps above the diffusion pumps.

10:30 a.m.: The vacuum within the chamber falls below 1000 microns and the blower pump is turned on. The two rotors within begin rotating, quickly reaching a

speed of over 2500 RPM. The rotors revolve in a synchronized motion, missing each other and the pump housing by only a few thousandths of an inch. As they rotate they grab any molecules that fall within their grasp and blow them on to the roughing pump. Because of their high speed, the rotors cannot be operated above 1000 microns, or they would windmill, creating enough heat to destroy the pump within minutes. A safety pressure switch monitors the input to the pump, vigilant and ready to turn off power to the pump should a leak occur. With the blower on, the vacuum within the chamber drops more quickly, and soon the chamber has fallen below 100 microns.

The bypass, intermediate, and emergency bypass diffusion pumps mounted on the outside of the chamber are turned on, coolant water is supplied to their outer jackets, and temperatures and flow rates are monitored.

11:00 a.m.: Within the main diffusion pumps, the oil has reached the boiling point. Oil vapors rise up the inner jacket until they reach the top of the pump where they are forced down through a multistage jet assembly, silently exiting at speeds of up to 750 miles per hour. Striking the water-cooled outer wall of the pump, the oil condenses and falls back to the reservoir below. The downward motion of the oil, as it leaves the jets, traps molecules that have entered into the top of the pump and sends them to the bottom where they are exhausted to the booster pumps. The booster pumps repeat the process and finally the molecules are driven into the roughing pumps.

Liquid nitrogen is introduced into the cryogenic trap within the manifold. As it cools, it begins to trap any errant molecules within its grasp, allowing them to escape only in the direction of the main diffusion pumps. With the chamber pressure nearing 50 microns, the main south diffusion pump valve is activated. Immediately the roughing pumps respond to the inrush of molecules. Their smooth drone is replaced with a lower beat as their rotors bite into the higher pressure.

Watchful eyes monitor the vacuum gauges within the diffusion pumps, ready to shut the valve should the internal pressure approach 100 microns. There is a momentary upsurge in the pressure reading and the pressure again begins to fall. The north diffusion pump valve is activated, but only a small quiver in the diffusion pump's vacuum gauge reveals its changed state.

11:00 p.m.: As the bypass, intermediate, and emergency bypass pumps reach operating temperature around the chamber, noticeable differences appear in the three areas inside the aluminizing chamber. The upper area falls below the 50 microns; although it still lags behind the diffusion pumps, it is nonetheless some 25 microns ahead of the intermediate vacuum area of the chamber. A chart recorder begins to record the slow drop of pressure within the chamber.

Workmen watch the gauges and monitor coolant water as the pressure indicates the transition from viscous to molecular flow — the pressure approaches one micron. Outside the chamber, peanuts arrive from a hidden source, an indication that things are going well, and the crunch of peanut shells mingles with the noise of the roughing pumps.

2:00 p.m., glow discharge: The vacuum inside the tank has reached a pressure of 2×10^{-5} microns. A bottle of oxygen is brought to the chamber and hose is connected from it to a needle valve on the side of the chamber. Both of the main diffusion pump valves and the roughing valve are closed and oxygen is bled into the chamber. When the atmosphere reaches 30 microns, the oxygen valve is closed. A switch is turned on and a autotransformer is used to adjust the voltage through the glow discharge ring near the top of the chamber to 200 volts with 10 amperes of current. Anyone who looks into the normally dark viewing ports sees a blue glow filling the chamber.

During the discharge process, molecules that stubbornly refused to move are now excited into moving, hopefully toward the manifold and the waiting diffusion pumps. After two minutes, the glow discharge is turned off and pumping is resumed. After about 30 minutes the pressure of the chamber has again fallen to the 10^{-5} micron range. The glow discharge is repeated five more times.

5:00 p.m., filament firing: The chamber has reached a vacuum of 5×10^{-5} microns and is finally ready for the aluminizing of the mirror. The firing transformer in place, electrical cables are rechecked, and a chart recorder is set to record the current as it passes through the filaments. The 360 filaments in the chamber are fired in pairs, with a voltage of 105 volts.

With everything in place, a worker sits in front of the recorder with the firing button in hand. The rotary switch on top of the tank is moved to the starting position. A man waits at the viewing port, anxious to watch the two filaments come to life. As others watch over the gauges and controls, the firing button is pushed, and the needle leaps to the top of the chart and then quickly descends because the current drops as a filament turns white hot.

Through the viewing port, a workman squints against the brightness of the two filaments and sees the Pyrex dish within. The honeycomb structure is clearly visible under the bright light. The filaments seem to dim and the chart recorder detects the increased current flow as the aluminum melts into the filament. As the filament brightens, the firing button is released — the recorder shows a downward slide, indicating the aluminum has vaporized.

The rotary switch is moved to its next position and the firing button again pushed. This time the workman at the viewing port sees the surface of the big mirror become reflective once again. The gauges monitoring the vacuum detect the increase in molecules during the firing and then settle down afterward to lower reading than before. As the process is repeated, the coating becomes more and more apparent. After ten pairs of filaments have been fired, the honeycomb structure of the mirror has disappeared beneath a fresh coat of shiny aluminum.

6:00 p.m.: All 180 filament pairs have been fired and all that remain are the fast-fire filaments which will be fired within a few seconds of each other over a 40-second period. This technique reduces the blue haze that can develop when using the large arrays of filaments needed to cover the entire mirror.

Tomorrow the whole process will be reversed. The chamber will be opened, and the mirror and its cell rolled under the telescope, raised, and bolted into place. The Cassegrain cage will be reinstalled, instrumentation fired up, and the work of the 200-inch Hale telescope will resume.

Robert Thicksten
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COMPLETE GUIDE TO BACK ISSUES

BY SUBJECT

ACCESSORIES AND GADGETS

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44	Kriege	David	Low-Tech R&D and Off-the-shelf Parts for Super-big Telescopes
43	Kanto	Veikko	Build a Periodic Error Corrector
41	Kriege	David	An Observing Ladder for Big Telescopes
33	Loewenstein	Jack	Remote Control Collimation
32	Coggan	Walter R.	A Sturdy, Low-Cost Wood Tripod
32	Shelley	John J.	An Adjustable Chair for Observers
30	Stacy	Gil	A Simple Practical Light Source for the Foucault Test
26	Prieske	Mike	Pail Rings Make Good Side Bearings
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15	Remaklus	Perry W.	Where to Find Parts for Telescopes
13	Kysor	Stephen K.	Using Setting Circles on a Dobsonian Telescope
13	Parlette	Ralph W.	A Precise Finder for Sun Telescopes
11	Papazian	Gary	A Peepsight Finder
10	Dakin	Ralph K.	Safe Solar Filtration
10	Huerkamp	Jack	Installing Bigger Circles on a Commercial Mount
9	Wisdom	Ronald	A Classic, Good-Looking Observatory and Dome that Turns on Golf Balls
7	Hamler	Walter E.	Equipment for Deep-Sky Astrophotography
7	Owen	E. Ken	A Handy Chair for Observing
2	Daggit	Al W.	Tripod Carrying Case
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42	West	Roger	A Simple Test of Binocular Collimation
37	Buchroeder	Richard A.	Revitalizing a 120mm WWII Binocular
34	Clark	Tom	A Dobsonian Mounting for Giant Binoculars
24	Cain	Lee	A 17.5" Transportable Dobsonian Binocular
20	Cain	Lee	Designing and Constructing a 13" Dobsonian Binocular
13	Butler	Norman	Dual 6" f/15 Cassegrains
11	Knab	Oscar R.	A 6" Folded Refractor with a Binocular Eyepiece Holder

CALCULATING AND COMPUTING

TM#	LAST NAME	FIRST NAME	ARTICLE
46	Kanto	Veikko	How to Build a Basic CCD Camera
45	George	Doug	Ross Null Software
43	Schettler	Michael	PC Control for the LAAS 31-Inch
38	Simpson	Ron	Titanium-Tubed and Computer-Controlled
22	Boyd	Louis	Telescopes for Microcomputer Control
17	Manly	Peter	A Solid-State TV Camera
15	Cox	Robert E.	Cox's Calculator and Computer Corner: Maksutov Ray Trace
10	Cox	Robert E.	Calculators for Telescope Design

CASSEGRAINS

TM#	LAST NAME	FIRST NAME	ARTICLE
45	Tomer	Andrew J.	A Motorized Cassegrain Secondary
31	Marche	Jordan D.	A Test for Figuring Cassegrain Secondaries
21	Reiffer	Raymond	Making a Compact Maksutov
20	Melsheimer	Frank	Cassegrain and Schmidt-Cassegrain Light Shield Design
15	Cox	Robert E.	Cox's Calculator and Computer Corner: Maksutov Ray Trace
14	Sutherland	Bill	Designing Maksutov Telescopes from Scratch
13	Butler	Norman	Dual 6" f/15 Cassegrains
7	Huber	Robert W.	A Mount for a Small Cassegrain
1	Buchroeder	Richard A.	Cassegrain Optical Systems

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38	Jones	Ed	A 6-inch Catadioptric Herschelian
31	Schalck	Robert	The Schalck-Newtonian
30	Sigler	Robert D.	A New Wide-Field, All-Spherical Telescope
29	Shafer	David	A Simple, High-Performance Amateur Telescope
27	Harlow	Michael J.	An Interference Test for Schmidt Corrector Plates
20	Melsheimer	Frank	Cassegrain and Schmidt-Cassegrain Light Shield Design
13	Rutten	H.G.J.	The Optical Performance of Eight-Inch Schmidt-Cassegrain Telescopes
11	Wilson	Jim A.	Notes on the Jones-Bird Telescope
9	Newton	Isaac	An Account of a New Catadioptrical Telescope
7	Wright	Ernest B.	The Questar 12
6	Allseits	John	Try a Tiny RFT
3	Bowen	Alfred V.	A Compact All-Spherical Catadioptric Newtonian Telescope
2	Sigler	Robert D.	Build This All-Spherical Relay Telescope

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46	Berry	Richard	Stellafane 1991

45	Ceravolo	Peter	RTMC 1991
45	Reeves	Robert	Western Hospitality Promotes Best Texas Star Party Yet (1991)
44	Berry	Richard	The 1991 Winter Star Party
43	Gada	Andreas	The Starfest 1990 Optical Quality Survey
42	Berry	Richard	AstroFest 1990: The Best Ever
42	Ceravolo	Peter	Stellafane 1990
42	Reeves	Robert	Telescope Making at the Texas Star Party (1990)
41	Berry	Richard	Riverside 1990
40	Berry	Richard	The 1990 Winter Star Party
38	Berry	Richard	AstroFest 1989
37	Berry	Richard	RTMC 1989
36	Berry	Richard	Super Seeing at the Winter Star Party (1988)
35	Berry	Richard	AstroFest 1988
35	Berry	Richard	Telescope Making at Alcon 1988
34	Eicher	David J.	1988: Record Year for the TSP
34	Eicher	David J.	Stellafane Pictorial (1988)
33	Berry	Richard	The 1988 Riverside Telescope Makers Conference
32	Cox	Robert E.	AstroFest 1987
31	Berry	Richard	Highlights of Stellafane 1987
31	Eicher	David J.	The Texas Star Party in 1987
30	Berry	Richard	RTMC 1987
27	Burnham	Robert	Texas Star Party 1985
27	Cox	Robert E.	Riverside 1985
25	Berry	Richard	Notes on AstroFest 1984
24	Berry	Richard	Fifty Years of Stellafane (1984)
23	Berry	Richard	The 1984 IAPPP, Riverside, and TSP Meetings
22	Eicher	David J.	The Texas Star Party — 1983
22	Stevens	Burton	AstroFest 1983
21	Berry	Richard	Stellafane 1983
21	Suiter	Dick	The 1983 Apollo Rendezvous and Telescope Fair
20	Cox	Robert E.	Riverside 1983
19	Berry	Richard	AstroFest 1982
17	Berry	Richard	Stellafane 1983 Pictorial
17	Cox	Robert E.	The 1983 Texas Star Party
16	Berry	Richard	1982 Riverside
15	Berry	Richard	AstroFest "Good in Spite of Mud" (1982)
13	Berry	Richard	Stellafane 1981
12	Berry	Richard	Riverside 1981
11	Eicher	David J.	Stellafane Past and Present (1981)
10	Berry	Richard	AstroFest 1980
9	Eicher	David J.	Apollo Rendezvous and Telescope Fair (1980)
8	Berry	Richard	Welcome to Riverside 1980
7	Maag	Russ	Mid-States Regional (1980)
5	Berry	Richard	Stellafane (1979)
4	Berry	Richard	Riverside 1979

DOBSONIANS

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45	Stewart	Ed	Doing it Right
44	Clark	Tom/Jean	A Light-weight 30-inch Dobsonian
44	Kriege	David	Low-Tech R&D and Off-the-shelf Parts for Super-big Telescopes
43	Schettler	Michael	PC Control for the LAAS 31-Inch
41	Drew	Bob	A Breakdown Telescope for Club Use
39	Clark	Tom	Supertune Your Telescope
35	Kriege	David	The Construction of Obsession I
35	Ravneberg	Ronald	Refining the Basic Dobsonian Design
35	Smitka	Peter	Dobsonian Evolution — The Telescope is Just One Part of an Observing System
28	Johnston	Steven W.	Construction of a Second 12.5" Tri-Schiefspiegler
26	Bernstein	Ralph	Friction Control
26	Chester	Geoffrey R.	Success Story
26	Coe	Steve	Evolution of a Dobsonian
26	Cretaux	Jean-Baptiste	Grozibou: A French Dobsonian
26	Fabre	Ray	Square vs. Round Dobsonians
26	Herdin	Jay	A Dobsonian Refractor on a Pier
26	Prieske	Mike	Pail Rings Make Good Side Bearings
26	Rayner	Gordon	The Delvin-AF Advantage
24	Cain	Lee	A 17.5" Transportable Dobsonian Binocular
24	Osypowski	Tom	A 16" Dobsonian on a Pursell Platform
20	Cain	Lee	Designing and Constructing a 13" Dobsonian Binocular
20	Dobson	John	Dobson on Dobsonians
17	Hamberg	Ivar	An Extremely Portable 17.5" Dobsonian
15	Dey	Tom	Dobsonian Developments
14	Wessling	Richard J.	A 20" Thin Mirror Dobsonian
14	White	Graeme	A Bending-Pier Telescope Mount
13	Kelly	Robert	"Night Owl" A Telescope Built with Gatorfoam
13	Kysor	Stephen K.	Using Setting Circles on a Dobsonian Telescope
13	Pursell	Wally	Making an Improved "Simple" Focuser
8	Berry	Richard	How to Control Friction in a Dobsonian Telescope
5	Kestner	Bob	The Dobsonian Telescope - II
4	Berry	Richard	The Dobsonian Telescope Part 1: It's Stability that Counts

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43	Kanto	Veikko	Build a Periodic Error Corrector
33	Wright	John	A Method of Making Precision Worm Gears
30	Inman	Jeff	The Hose-Clamp Drive
26	Bernstein	Ralph	Friction Control
26	Haasteren	Alb. v.	The Hypoclycloidal Drive
26	Rochette	Martin	An Alt-azimuth Mounting with Equatorial Drive
22	Wadman	Sipke	Guiding for Astrophotography
21	Dodson	Steve	The Double Hamon Cam Drive
19	Migiel	Tom	Making Correctors for Wright-Newtonian Telescopes
11	Hulme	Kenneth S.	A Sand-Powered Drive
10	Bailey	James. R.	A Basic RC Drive Corrector
10	Mulford	Bob	A Simple Crystal Controlled Drive Corrector
4	Sandy	Robert L.	A Homemade Declination Drive System

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43	Kanto	Veikko	Build a Periodic Error Corrector
43	Schettler	Michael	PC Control for the LAAS 31-Inch
38	Simpson	Ron	Titanium-Tubed and Computer-Controlled
22	Boyd	Louis	Telescopes for Microcomputer Control
20	Schultz	Sherman W.	Glass and Grit Seen with the Scanning Electron Microscope
17	Manly	Peter	A Solid-State TV Camera
2	Wyant	Bill	A Handsome 10-inch Newtonian

EQUATORIAL PLATFORMS

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35	Smitka	Peter	Dobsonian Evolution — The Telescope is Just One Part of an Observing System
24	Osypowski	Tom	A 16" Dobsonian on a Pursell Platform
21	Barclay	Bob	More on Hydraulic Drive Equatorial Platforms
20	Holden	Edward	The XXXVI-Inch Equatorial of the USNO
19	Martinez	Tom	A State-of-the-Art Poncet Equatorial Platform
19	Pursell	Wally	Pursell's Platform: A Southern Alternative to the Poncet

17	Barclay	Bob	An Equatorial Platform with a Hydraulic Escapement
15	Olson	Chuck	Nested-Corner Equatorial Platforms
14	Berry	Richard	Dual-Axis Equatorial Platforms
10	Poncet	Adrien	Poncet on Poncet
9	Lasher	Richard W.	The Poncet Mounting
8	Cox	Robert E.	The Poncet Mount
8	Wooten	Wayne	Converting Fork Alt-Azimuths into Equatorials

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29	Klee	H.W.	The Pretoria Eyepiece
25	Buchroeder	Richard A.	Eyepieces
21	Clarke	Thomas L.	A New Flat-Field Eyepiece
20	van Venrooij	M.A.M.	The Nagler 13: A Remarkable Telescope Eyepiece
19	Rutten	H.G.J.	Six Eyepieces Compared
18	Lindberg	Stephen	A Modified Cheshire Eyepiece for Collimation
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11	Spry	Reg	The Crayford

FOCUSERS

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45	Tomer	Andrew J.	A Motorized Cassegrain Secondary
36	Scott	Don	The "Master Plumber" Focuser
13	Bartels	John	A Multi-Eyed Telescope
13	Pursell	Wally	Making an Improved "Simple" Focuser
2	Mayer	Ben	Accurate Focusing

HISTORY

TM#	LAST NAME	FIRST NAME	ARTICLE
46	Thicksten	Robert	Aluminizing the 200-Inch
43	Legrand	Christian D.	The Amateur Paradise of Dany Cardoen
40	Miller	Ferdinand	A Model of Herschel's Uranus Telescope
40	TM	Readers of	Robert Edward Cox, Telescope Nut
37	Bachtell	David	Restoring the 12-inch Alvan Clark & Son Refractor of the Witte Observatory
37	Buchroeder	Richard A.	Revitalizing a 120mm WWII Binocular
34	Schroter	Johann	Building a 27-foot Newtonian Telescope
32	Huey	Cecil O.	A Replica of Galileo's Telescope
31	Bunge	Robert	The Warren Rupp Observatory
31	Sanford	John	The OCA's Anza Observatory
28	Buchroeder	Richard A.	Interview with Horace Dall
24	Berry	Richard	Fifty Years of Stellafane (1984)
24	Berry	Richard	The U and C Ten Meter Telescope
23	Levy	David H.	Telescopes and Tombaugh
21	Jones	Timothy R.	The Fitz/Clark 13-Inch Refractor of Allegheny Observatory
20	Cox	Robert E.	Telescope Making Today
20	Dobson	John	Dobson on Dobsonians
20	Holden	Edward	The XXXVI-Inch Equatorial of the USNO
20	TM	Editors of	Guide to Back Issues of TM
19	Pfeiffer	Robert	The Amateur Space Telescope: ISRG Update
18	Wessling	Richard J.	Apollo Rendezvous 1982
17	Sperling	Norman	Marshal Martz's 76cm Telescope
15	Hedervari	Peter	The Georgiana Observatory
15	Rafferty	Theodore J.	Refurbishing the U.S. Naval Observatory's 1892 Saegnuller 12" Refractor
10	Urbaetis	Mark	John A. Brashear Telescope Maker, Scientist, Humanitarian
9	Eicher	David J.	Apollo Rendezvous and Telescope Fair (1980)
9	Grinder	John	The Amateur Space Telescope Project
7	Dick	Thomas	Lord Rosse's Great Telescope
3	Hoefer	Roger	Apollo Observatory's 19.38" Dall-Kirkham Telescope
2	Zit	Raymond E.	Amateur Astronomy in Milwaukee

INTERFEROMETERS

TM#	LAST NAME	FIRST NAME	ARTICLE
2	Sigler	Robert D.	The Fizeau Interferometer

LENS MAKING

TM#	LAST NAME	FIRST NAME	ARTICLE
45	Shafer	David	How to Make a Coma Corrector with Off-the-shelf Optics
44	Douglas	Robert B.	A New Apochromatic Doublet
38	Shafer	David	More High-Performance Designs for Amateur Telescopes
34	Cox	Robert E.	Editorial: Optical Work Is Hazardous
28	Christen	Roland	Design and Construction of a Super Planetary Telescope Objective
28	Cox	Robert E.	Cementing Achromatic Lenses
18	DeVany	Arthur S.	Books: Master Optical Techniques
13	Cox	Robert E.	Lens Design Fundamentals
3	Wilson	Jim A.	How to Make a Lens
1	Schultz	Sherman W.	Making Pitch Laps

MIRROR CELLS

TM#	LAST NAME	FIRST NAME	ARTICLE
34	Scott	Don	A Removable Mirror Cell
26	Chandler	David	Flotation Cell Design
14	Hill	John M.	Pyrex Honeycomb Mirrors
6	Cox	Robert E.	Better Mirror Cells
4	Perry	Joseph G.	An Amateur-Built Reflector with an 80cm f/2.4 Primary

MIRROR MAKING

TM#	LAST NAME	FIRST NAME	ARTICLE
46	Ceravolo	Peter	Coating Cosmetics
46	Ceravolo	Peter	Making Mirrors: The Art of Aluminizing
46	Montierth	George	How to Ship Your Mirror
46	Thicksten	Robert	Aluminizing the 200-Inch
45	George	Doug	Ross Null Software
45	Mulherin	James	A Simple Procedure for Producing a Yolo Telescope
39	Ceravolo	Peter	High-Finesse Figuring
39	Marche	Jordan D.	The Spectroscopic Survey Telescope
38	McCurdy	Gaylord	Building a Pseudo-Automated Grinding Machine
36	Scott	Don	The Cost of Telescope Mirrors
34	Cox	Robert E.	Editorial: Optical Work Is Hazardous
16	Kestner	Bob	Grinding, Polishing, and Figuring Thin Mirrors, Part 3: Figuring
13	Kestner	Bob	Grinding, Polishing, and Figuring Thin Telescope Mirrors, Part 2: Polishing
12	Kestner	Bob	Grinding, Polishing, and Figuring Thin Telescope Mirrors, Part 1: Grinding
11	Covington	Paul T.	Mirror Curvature During Grinding: A Mathematical Treatment
9	Schultz	Sherman W.	The Macalester Four-Goal System of Mirror Making and the Ronchi Test
7	Cox	Robert E.	Improving Telescope Performance Part 2: Secondary Mirrors and Spiders
7	Waineo	Thomas	A Portable Polishing Mirror
6	Aguilar	David A.	Mirror Grinding with a Channeled Tool
6	Cox	Robert E.	Better Mirror Cells
2	Berry	Richard	What's My Abrasive?
1	Schultz	Sherman W.	Making Pitch Laps

MISCELLANEOUS

TM#	LAST NAME	FIRST NAME	ARTICLE
46	TM	Staff of	Comprehensive Index to TM
43	Legrand	Christian D.	The Amateur Paradise of Dany Cardoen

42	Ceravolo	Peter	HST, the Null Test, and Technological Arrogance: Three Views
40	Miller	Ferdinand	A Model of Herschel's Uranus Telescope
40	TM	Readers of	Robert Edward Cox, Telescope Nut
39	Lappin	Gerald R.	Solor Newtonian
32	Huey	Cecil O.	A Replica of Galileo's Telescope
29	Milovsky	Richard A.	Permuted Index of TM #1 to #28
25	Schultz	Sherman W.	The Eye: Your Window to the Universe
21	Cox	Robert E.	A "Twitcher" Telescope
21	Suiter	Dick	The 1983 Apollo Rendezvous and Telescope Fair
20	Cox	Robert E.	Telescope Making Today
20	TM	Editors of	Guide to Back Issues of TM
19	Pfeiffer	Robert	The Amateur Space Telescope: ISRG Update
18	Wessling	Richard J.	Apollo Rendezvous 1982
15	Remaklus	Perry W.	Where to Find Parts for Telescopes
14	Ritschel	Kevin	Commercial Telescopes: the View from the Supply Side
12	White	Graeme	The Cost of Amateur Telescope
10	Urbaetis	Mark	John A. Brashear Telescope Maker, Scientist, Humanitarian
9	Grinder	John	The Amateur Space Telescope Project
9	Ritschel	Kevin	Telescopes for the Future
7	Ainge	Chuck A.	A Shelter from Streetlights
7	Maag	Russ	Mid-States Regional (1980)
7	Nova News	Nova News	The 20-Incher in the Rhubarb Patch
3	Stull	John	Design of a Large "Small" Telescope
2	Zit	Raymond E.	Amateur Astronomy in Milwaukee

MOUNTINGS

TM#	LAST NAME	FIRST NAME	ARTICLE
44	Clark	Tom/Jean	A Light-weight 30-inch Dobsonian
39	Moerke	David	A Split-Ring Equatorial
34	Clark	Tom	A Dobsonian Mounting for Giant Binoculars
34	Lopez Velez	Rafael	A "Dampier" Pier Removes Vibrations
30	Inman	Jeff	The Hose-Clamp Drive
30	Woods	A.L.	An Equatorial Plate Fork Mounting
27	Pearson	Joe	An Equatorial Split-Ring Telescope
27	Woods	A.L.	Wooden Fork Mounting
26	Rochette	Martin	An Alt-azimuth Mounting with Equatorial Drive
24	Allen	D. Eric	A Fork Equatorial for 17.5" Optics
24	Osypowski	Tom	A 16" Dobsonian on a Pursell Platform
23	Poncet	Adrien	The 2DS: A New Mounting
20	Hooten	Keven	An Unconventional Equatorial Mounting
19	Kysor	Stephen K.	Making an Observing Table and Cover for a 10" Reflector
14	Dodson	Steve	A Poncet/Dobson Hybrid Mounting for a 22" Reflector
14	White	Graeme	A Bending-Pier Telescope Mount
11	Andreassen	Richard	An 8" Reflector on a Homebuilt Mounting
11	Berry	Richard	Yoke and Cross-Axis Mountings Made Easy
11	Spry	Reg	The Crayford
10	Huerkamp	Jack	Installing Bigger Circles on a Commercial Mount
8	Wooten	Wayne	Converting Fork Alt-Azimuths into Equatorials
7	Berry	Richard	A 20" Newtonian on an Alt-azimuth Mount
7	Cox	Robert E.	Improving Telescope Performance Part 2: Secondary Mirrors and Spiders
7	Doyal	Paul	Equatorial Mount for a 10" Reflector
7	Gercke	V.	To Giraffe or Not to Giraffe
7	Huber	Robert W.	A Mount for a Small Cassegrain
7	Hulme	Kenneth S.	Build This Simple Astro Mount
6	Ely	Richard A.	The Cheap, No Legs, Stable Portable Telescope Mount
6	Wooten	Wayne	The Easy Easel Equatorial Mount for a 4" RFT
4	Berry	Richard	The Dobsonian Telescope Part 1: It's Stability that Counts
2	Daggit	Al W.	Tripod Carrying Case
2	Sigler	Robert D.	The Fizeau Interferometer
2	Smith	Stephen B.	A Compact 6-Inch Refractor
1	Sanders	Frank C.	A Portable Wooden Yoke Mounting

NEWTONIANS

TM#	LAST NAME	FIRST NAME	ARTICLE
43	Harris	Luis A.	A Split-Ring Newtonian for 9° Latitude
42	Viscome	George	Building a Yoke-Mounted Telescope
41	Shafer	David	A Simple Unobstructed Telescope
39	Lappin	Gerald R.	Solor Newtonian
38	Sasian	Jose	A 6-inch Yolo-Newtonian
37	Bunge	Robert	A High-Performance 6-inch Reflector
37	Kriege	David	Building the 25-inch "Obsession 2"
35	Kriege	David	The Construction of Obsession I
35	Ravneberg	Ronald	Refining the Basic Dobsonian Design
35	Rutten	Harrie	The Rutten Newtonian
31	Schalck	Robert	The Schalck-Newtonian
29	O'Brien	Thomas P.	Building a 14-inch Ball-in-socket Telescope
26	Holman	Marchal	An Alabama Amateur's 20.5-Inch Telescope
23	Reeve	Gregory	The Ultimate Newtonian
22	Allen	D. Eric	Updating Newtonian Collimation
22	Bunge	Robert	An Ultra-Portable 6" Reflector
21	Dawson	James P.	A 12" Reflector with a Run-off Observatory
19	Kysor	Stephen K.	Making an Observing Table and Cover for a 10" Reflector
19	Migiel	Tom	Making Correctors for Wright-Newtonian Telescopes
19	Suiter	Dick	An Easy Design for a Truly Portable 17.5" Reflector
18	Greska	Tom	Constructing the "Wooden Wonder"
17	Chandler	David	A 24" Equatorial Reflector
14	Dodson	Steve	A Poncet/Dobson Hybrid Mounting for a 22" Reflector
12	Stoltzmann	David	Newtonian Aberrations
11	Andreassen	Richard	An 8" Reflector on a Homebuilt Mounting
10	Levy	David H.	A Telescope for Children
9	Berry	Richard	Newtonian Telescopes
7	Berry	Richard	A 20" Newtonian on an Alt-azimuth Mount
7	Dick	Thomas	Lord Rosse's Great Telescope
7	Doyal	Paul	Equatorial Mount for a 10" Reflector
7	Lawson	Keith	A Homemade Finder
6	Lazerson	Howard	Two Tiny Multi-purpose Telescopes
6	Shaffer	Richard	The Serious Beginner's Basic 8" Scope
6	Wooten	J. Wayne	The Easy Easel Equatorial Mount for a 4" RFT
5	Dessert	Thomas L.	An Observatory for Deep-Sky Astrophotography
5	Provin	Robert	Telescope Design for Deep-Sky Photography
4	Perry	Joseph G.	An Amateur-Built Reflector with an 80cm f/2.4 Primary
3	Bowen	Alfred V.	A Compact All-Spherical Catadioptric Newtonian Telescope
3	Herschel	William	Description of a Forty-Feet Reflecting Telescope
3	Lasher	Richard W.	A 10-inch Portable Open Tube Newtonian
2	Stephan	Christopher	A 14-inch Reflector
2	Wyant	Bill	A Handsome 10-inch Newtonian
1	Berry	Richard	An Inexpensive 4" f/10 Reflector

OBSERVATORIES

TM#	LAST NAME	FIRST NAME	ARTICLE
43	Legrand	Christian D.	The Amateur Paradise of Dany Cardoen

42	Viscome	George	Building a Yoke-Mounted Telescope
41	Beaman	Barry	How to Paint an Observatory Dome
40	Thompson	Gregg D.	Split Roll-Off Rood Observatories
37	Bachtell	David	Restoring the 12-inch Alvan Clark & Son Refractor of the Witte Observatory
37	Mattingly	Phillip	Nightwatch Observatory
36	Nichols	Nick	Building a Dream Observatory
36	Reeves	Robert	Cabinets Help a Crowded Observatory
34	Berry	Richard	Building a "Two-Weekend" Observatory
33	Hunter	Tim	Design Your Observatory for Optimum Seeing
32	Williams	Ernie	Homemade Portable Observatory
31	Bunge	Robert	The Warren Rupp Observatory
31	Clark	Tom	Rolling Observatory
31	Sanford	John	The OCA's Anza Observatory
30	Tempest	Terrence	Watchcroft Observatory: The Most Westerly Dome in England
29	Barclay	Jim	Building the Manly "Flip-Top" on the Cheap, Down Under
29	Colfax	Drew	A Counterweighted Roll-Roof Observatory
24	Warner	Jerry R.	Dome Tracks and Tracking Systems
23	Bokensberg	Alec	el Observatorio de Roque de los Muchachos
22	Bresnick	Herbert	Building a Geodesic Observatory
21	Dawson	James P.	A 12" Reflector with a Run-off Observatory
21	Jones	Timothy R.	The Fitz/Clark 13-Inch Refractor of Allegheny Observatory
18	Dey	Tom	You Can Take it with You!
18	Warner	Jerry R.	Got a Leaking Dome? I Sure Did!
17	Houk	H.G.	The Grace Observatory
17	Ratledge	D.	A Glass Fiber Obervatory
15	Hedervari	Peter	The Georgiana Observatory
12	Urbaetis	Mark	Constructing a Club Observatory
10	McDaniel	Ronald B.	How to Build a Garage-top Observatory
10	Reisenweber	Robert C.	Rolling Ridge Observatory
9	Wisdom	Ronald	A Classic, Good-Looking Observatory and Dome that Turns on Golf Balls
8	Happe	Norman L.	Golden Ridge Observatory
8	Spry	Reg	Rotating Shed Observatory
7	Ainge	Chuck A.	A Shelter from Streetlights
7	Angelow	Larry	Observing Through a Roof Hatch
7	Kandle	Paul D.	Wojciech Konefal Observatory
5	Dessert	Thomas L.	An Observatory for Deep-Sky Astrophotography
5	Dodds	Earle F.	Mockingbird Hill Observatory
5	Genet	Russel M.	Fairborn Observatory: It's Equipped for Photoelectric Photometry
4	Dodds	Earle F.	Pier Heads for Backyard Observatories
4	Renner	Thomas	Scuppernong Observatory
4	Zeh	Howard F.	A Ready-Made Building for a Backyard Observatory
3	Hoefer	Roger	Apollo Observatory's 19.38" Dall-Kirkham Telescope
3	Simpson	John W. H.	A Three-Weekend Observatory
3	Tkach	John R.	Build Your Own Telescope House
2	Ashurst	Brian	Tularcitos Obsevatory
2	Dodds	Earle F.	Permanent Piers for Backyard Observatories

OPTICAL DESIGN

TM#	LAST NAME	FIRST NAME	ARTICLE
45	Shafer	David	How to Make a Coma Corrector with Off-the-shelf Optics
40	Berry	Richard	Central Obstructions and the Airy Disk
39	Ceravolo	Peter	The Ross Null Test
39	Marche	Jordan D.	The Spectroscopic Survey Telescope
38	Sasian	Jose	A 6-inch Yolo-Newtonian
38	Shafer	David	More High-Performance Designs for Amateur Telescopes
37	Sasian	Jose	How to Design a Yolo Telescope
35	Rutten	Harrie	The Rutten Newtonian
33	Buchroeder	Richard A.	In Search of the Perfect Eyepiece
31	Cox	Robert E.	Optical Experts Comment on the TSP
31	Schalck	Robert	The Schalck-Newtonian
30	Sigler	Robert D.	A New Wide-Field, All-Spherical Telescope
29	Klee	H.W.	The Pretoria Eyepiece
29	Shafer	David	A Simple, High-Performance Amateur Telescope
29	Suiter	Dick	Changing the Aperture Pupil
28	Christen	Roland	Design and Construction of a Super Planetary Telescope Objective
28	Wessling	Richard J.	Building a 12.5" Buchroeder Tri-Schiefspiegler
18	DeVany	Arthur S.	Books: Master Optical Techniques
2	Sigler	Robert D.	Build This All-Spherical Relay Telescope
1	Buchroeder	Richard A.	Cassegrain Optical Systems

OPTICAL QUALITY

TM#	LAST NAME	FIRST NAME	ARTICLE
43	Gada	Andreas	The Starfest 1990 Optical Quality Survey
40	Berry	Richard	Central Obstructions and the Airy Disk
31	Cox	Robert E.	Optical Experts Comment on the TSP
29	Suiter	Dick	Changing the Aperture Pupil
28	Suiter	Dick	Modifications to the Diffraction Image Caused by Surface Roughness in Mirrors
13	Rutten	H.G.J.	The Optical Performance of Eight-Inch Schmidt-Cassegrain Telescopes
12	Stoltzmann	David	Newtonian Aberrations

OPTICAL TESTING

TM#	LAST NAME	FIRST NAME	ARTICLE
45	George	Doug	Ross Null Software
42	Ceravolo	Peter	HST, the Null Test, and Technological Arrogance: Three Views
42	West	Roger	A Simple Test of Binocular Collimation
41	Ceravolo	Peter	The Nuances of Optical Testing
39	Ceravolo	Peter	The Ross Null Test
33	Follett	Robert C.	Efficient Mirror Testing
32	Suiter	Dick	Testing Paraboloidal Mirrors
31	Marche	Jordan D.	A Test for Figuring Cassegrain Secondaries
30	Slade	Brian	A Foucault Jest
30	Stacy	Gil	A Simple Practical Light Source for the Foucault Test
28	Suiter	Dick	Modifications to the Diffraction Image Caused by Surface Roughness in Mirrors
27	Harlow	Michael J.	An Interference Test for Schmidt Corrector Plates
23	Stoltzman	David	Foucault Knife-Edge Testing
22	Suiter	Dick	On Slitless Testers
21	Gregory	John F.	The H'tanU' Curve
18	DeVany	Arthur S.	Books: Master Optical Techniques
18	Rutten	H.G.J.	The Optical Performance of Six Astrocameras
16	Kestner	Bob	Grinding, Polishing, and Figuring Thin Mirrors, Part 3: Figuring
16	van Venrooij	M.A.M.	Contrast Rendition and Resolving Power in Telescopes Used Visually
16	Woods	A.L.	Collimation for a Kutter Tri-Schiefspiegler
13	Frank	John M.	The RFT Central Spot
12	Stoltzmann	David	Newtonian Aberrations
11	Raycraft	Alan	Ronchi Test with a Null Lens
11	Waineo	Thomas	A Reflecting Null Test for Paraboloids
9	Schultz	Sherman W.	The Macalester Four-Goal System of Mirror Making and the Ronchi Test
7	Woods	A.L.	Zeroing in with a Long Radius Mirror

6	Cox	Robert E.	Optical Testing with the Wire Test
6	Miller	Robert P.	Stalking the Wild Paraboloid
6	Woods	A.L.	A Simple Knife-edge Tester
6	Woods	A.L.	How to Make Focograms
2	McGuire	Daniel E.	Zonal Test Tolerances

PHOTOGRAPHY

TM#	LAST NAME	FIRST NAME	ARTICLE
46	Kanto	Veikko	How to Build a Basic CCD Camera
33	Beish	Jeff	Building a Precise Shutter
22	Wadman	Sipke	Guiding for Astrophotography
18	Rutten	H.G.J.	The Optical Performance of Six Astrocameras
14	Berry	Richard	Dual-Axis Equatorial Platforms
14	Housekeeper	Dick	Astrophotography on a Shoestring Budget w/Dobson, Poncet, Kodak, et. al.
13	Jones	Donn E.	A Low-Cost Film Hypersensitizing Unit
8	Buchroeder	Richard A.	The Houghton Camera
7	Hamler	Walter E.	Equipment for Deep-Sky Astrophotography
5	Provin	Robert	Telescope Design for Deep-Sky Photography
3	Stull	John	Jet to the Moon

PHOTOMETRY

TM#	LAST NAME	FIRST NAME	ARTICLE
7	Genet	Russel M.	The PEP Gang
5	Genet	Russel M.	Fairborn Observatory: It's Equipped for Photoelectric Photometry

REFRACTORS

TM#	LAST NAME	FIRST NAME	ARTICLE
44	Myers	Larry	Constructing a Large Brass Refractor
40	Cartwright	David	Building a 4-Inch Plywood Refractor
37	Bachtell	David	Restoring the 12-inch Alvan Clark & Son Refractor of the Witte Observatory
36	Sorenson	Andrew	Building a 6-inch f/21 Littrow Refractor
32	Cox	Robert E.	Folding Refractors for Portability
28	Christen	Roland	Design and Construction of a Super Planetary Telescope Objective
26	Herdin	Jay	A Dobsonian Refractor on a Pier
21	Jones	Timothy R.	The Fitz/Clark 13-Inch Refractor of Allegheny Observatory
20	Holden	Edward	The XXXVI-Inch Equatorial of the USNO
18	Lones	Dain B.	Notes on an 8" Achromatic Refractor
15	Rafferty	Theodore J.	Refurbishing the U.S. Naval Observatory's 1892 Saegnuller 12" Refractor
13	Zaranka	William	A Poet's Refractor
11	Knab	Oscar R.	A 6" Folded Refractor with a Binocular Eyepiece Holder
7	Gercke	V.	To Giraffe or Not to Giraffe
2	Smith	Stephen B.	A Compact 6-Inch Refractor

SUPPLIES

TM#	LAST NAME	FIRST NAME	ARTICLE
44	Kriege	David	Low-Tech R&D and Off-the-shelf Parts for Super-big Telescopes
42	Hughes	Larry	Constructing Foam and Fiberglass Tubes
34	Cox	Robert E.	What's New? Products for Telescope Makers
26	Rayner	Gordon	The Delvin-AF Advantage
15	Remaklus	Perry W.	Where to Find Parts for Telescopes

TELESCOPE DESIGN

TM#	LAST NAME	FIRST NAME	ARTICLE
45	Mulherin	James	A Simple Procedure for Producing a Yolo Telescope
45	Stewart	Ed	Doing it Right
44	Clark	Tom/Jean	A Light-weight 30-inch Dobsonian
44	Myers	Larry	Constructing a Large Brass Refractor
43	Harris	Luis A.	A Split-Ring Newtonian for 9° Latitude
43	Sasian	Jose	Variations on the Schiefspiegler
42	Hughes	Larry	Constructing Foam and Fiberglass Tubes
42	Viscome	George	Building a Yoke-Mounted Telescope
41	Drew	Bob	A Breakdown Telescope for Club Use
41	Shafer	David	A Simple Unobstructed Telescope
40	Cartwright	David	Building a 4-Inch Plywood Refractor
39	Clark	Tom	Supertune Your Telescope
39	Marche	Jordan D.	The Spectroscopic Survey Telescope
39	Moerke	David	A Split-Ring Equatorial
38	Simpson	Ron	Titanium-Tubed and Computer-Controlled
37	Kriege	David	Building the 25-inch "Obsession 2"
36	Sorenson	Andrew	Building a 6-inch f/21 Littrow Refractor
35	Kriege	David	The Construction of Obsession I
35	Ravneberg	Ronald	Refining the Basic Dobsonian Design
35	Smitka	Peter	Dobsonian Evolution — The Telescope is Just One Part of an Observing System
34	Scott	Don	A Removable Mirror Cell
32	Cox	Robert E.	Folding Refractors for Portability
32	Huey	Cecil O.	A Replica of Galileo's Telescope
29	O'Brien	Thomas P.	Building a 14-inch Ball-in-socket Telescope
28	Pike	Rob	On the Construction of Foamcore Telescope Parts
27	Pearson	Joe	An Equatorial Split-Ring Telescope
26	Fabre	Ray	Square vs. Round Dobsonians
21	Raether	Don	Wooden Tubes for Telescopes
19	Suiter	Dick	An Easy Design for a Truly Portable 17.5" Reflector
18	Greska	Tom	Constructing the "Wooden Wonder"
17	Chandler	David	A 24" Equatorial Reflector
17	Hamberg	Ivar	An Extremely Portable 17.5" Dobsonian
16	Woods	A.L.	Building a Kutter 3-Mirror Tri-Schiefspiegler
15	Dey	Tom	Dobsonian Developments
14	Rutten	H.G.J.	Nine Telescope Systems Compared
10	Cox	Robert E.	Calculators for Telescope Design
5	Kestner	Bob	The Dobsonian Telescope - II
5	Provin	Robert	Telescope Design for Deep-Sky Photography
4	Berry	Richard	The Dobsonian Telescope Part 1: It's Stability that Counts
1	Knab	Oscar R.	Making a 3-Inch Schiefspiegler

TELESCOPE MECHANICS

TM#	LAST NAME	FIRST NAME	ARTICLE
44	Myers	Larry	Constructing a Large Brass Refractor
32	Coggan	Walter R.	A Sturdy, Low-Cost Wood Tripod
26	Cox	Robert E.	Telescope Tubes: Good, but Mostly Bad
26	French	Alan	Finishing Cardboard Tubes
26	Herdin	Jay	A Dobsonian Refractor on a Pier
14	White	Graeme	A Bending-Pier Telescope Mount
11	Berry	Richard	Yoke and Cross-Axis Mountings Made Easy
10	Mulford	Bob	A Simple Crystal Controlled Drive Corrector
6	Ely	Richard A.	The Cheap, No Legs, Stable Portable Telescope Mount

THIN MIRRORS

TM#	LAST NAME	FIRST NAME	ARTICLE
26	Chandler	David	Flotation Cell Design
16	Kestner	Bob	Grinding, Polishing, and Figuring Thin Mirrors, Part 3: Figuring
13	Kestner	Bob	Grinding, Polishing, and Figuring Thin Telescope Mirrors, Part 2: Polishing
12	Kestner	Bob	Grinding, Polishing, and Figuring Thin Telescope Mirrors, Part 1: Grinding
14	Wessling	Richard J.	A 20" Thin Mirror Dobsonian

BY AUTHOR

A

LAST NAME	FIRST NAME	ARTICLE TITLE	TM#
Aguilar	David A.	Mirror Grinding with a Channeled Tool	6
Ainge	Chuck A.	A Shelter from Streetlights	7
Allen	D. Eric	Updating Newtonian Collimation	22
Allen	D. Eric	A Fork Equatorial for 17.5" Optics	24
Allseits	John	Try a Tiny RFT	6
Andreassen	Richard	An 8" Reflector on a Homebuilt Mounting	11
Andreic	Zelijko	A Simple, Practical Guide Eyepiece	11
Angelow	Larry	Observing Through a Roof Hatch	7
Ashurst	Brian	Tularcitos Obsevatory	2

B

LAST NAME	FIRST NAME	ARTICLE TITLE	TM#
Bachtell	David	Restoring the 12-inch Alvan Clark & Son Refractor of the Witte Observatory	37
Bailey	James. R.	A Basic RC Drive Corrector	10
Barclay	Bob	An Equatorial Platform with a Hydraulic Escapement	17
Barclay	Bob	More on Hydraulic Drive Equatorial Platforms	21
Barclay	Jim	Building the Manly "Flip-Top" on the Cheap, Down Under	29
Bartels	John	A Multi-Eyed Telescope	13
Beaman	Barry	How to Paint an Observatory Dome	41
Beish	Jeff	Building a Precise Shutter	33
Bernstein	Ralph	Friction Control	26
Berry	Richard	An Inexpensive 4" f/10 Reflector	1
Berry	Richard	What's My Abrasive?	2
Berry	Richard	The Dobsonian Telescope Part 1: It's Stability that Counts	4
Berry	Richard	Riverside 1979	4
Berry	Richard	Stellafane	5
Berry	Richard	A 20" Newtonian on an Alt-azimuth Mount	7
Berry	Richard	How to Control Friction in a Dobsonian	8
Berry	Richard	Welcome to Riverside 1980	8
Berry	Richard	Newtonian Telescopes	9
Berry	Richard	AstroFest 1980	10
Berry	Richard	Yoke and Cross-Axis Mountings Made Easy	11
Berry	Richard	Riverside 1981	12
Berry	Richard	Stellafane 1981	13
Berry	Richard	Dual-Axis Equatorial Platforms	14
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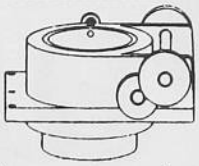

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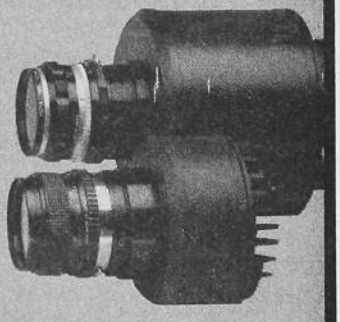

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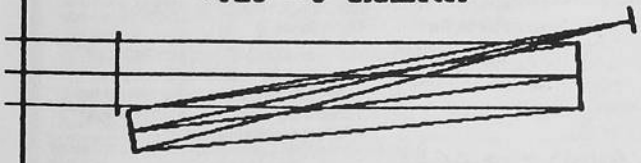

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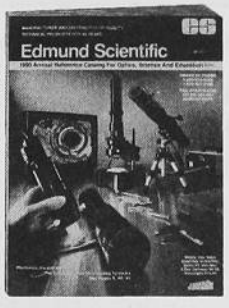

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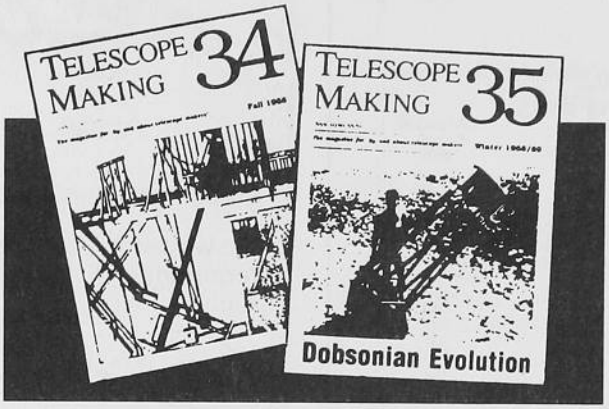

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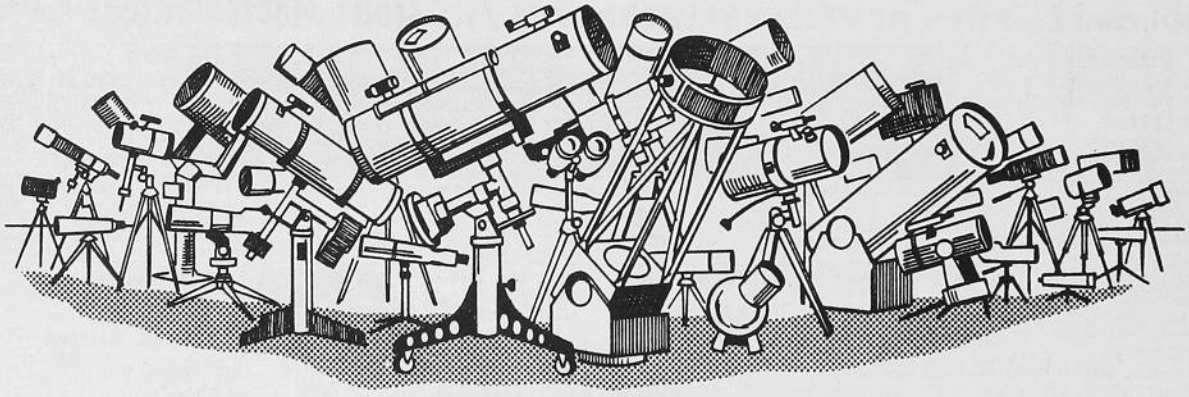

$20 will get you $1,000,000 worth of scopes

That's how many telescopes are for sale each year in *The Starry Messenger*, the nation's oldest and largest classified shopper devoted solely to telescopes, eyepieces and accessories for astronomy.

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Every month we print classified ads for Astro-Physics refractors, TeleVue eyepieces, Coulter Dobsonians, Meade & Celestron SCTs - you name it - all at swap table prices. Need magazine back issues? ATM supplies? Star charts? A drive corrector? *The Starry Messenger* classified shopper has whatever you're looking for.

And no wonder. After all, *more amateur astronomers sell their telescopes and accessories through TSM than anywhere else.* Doesn't it make sense to check *The Starry Messenger* first?

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Send no money - just your advertisement. If your ad doesn't sell, we'll keep running it until you find a buyer. When your ad is successful and you've made your sale, you simply pay a 4% commission. A *Starry Messenger* classified ad will turn your telescope into cash fast - in as little as 2 weeks!

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Send us $20 ($25 in Canada) and we'll send you a million dollars worth of telescopes in twelve monthly issues. And if you don't save $20 the first time you buy something we'll refund the unused portion. So write us or call today - don't miss another ad-packed issue!

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- Digital decl. readout to 10 arc-min
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- Motor drive **not required**
- Just sight two stars!
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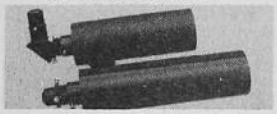
- NEW SKY VECTOR II w/1500 object memory

LUMICON Sky Vector™ (state scope) **$398**
SKY VECTOR II w/1500 object memory **$589**
Sky Vector™ KIt (you supply hardware) **$369**
Pair digital shaft encoders (for 2nd scope) **$149**

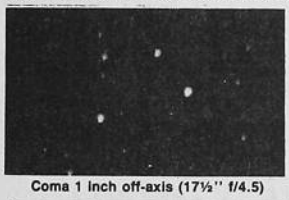
LUMICON 50mm, 80mm SUPER-FINDER™



Visual Astronomers perfer the LUMICON 80mm SUPER-FINDER™, since hundreds of deep-sky objects, including most Messier objects, are visible directly. SUPER-FINDERS also make nice small portable telescopes. 80mm aperture, F=300mm coated achromat.

1¼" 50mm Finderscope **$59.50**, right-angle **$89.50**
1¼" straight-thru 80mm SUPER-FINDER **$169**
1¼" right-angle 80mm Super Finder **$179.50**
1¼" right-angle version, w/star diagonal **$209**
25mm Cross-hair 1¼" eyepiece (12X) **$29**
1¼" Star Diagonal .. **$39**, 2" Star Diagonal .. **$159**
1¼" Amici Prism diag. for correct left-right views **$69.50**

COMA CORRECTOR LENS



Coma 1 inch off-axis (17½" f/4.5)

Same Field with LUMICON coma corrector lens; note smaller, more numerous stars.

This computer-designed LUMICON 2" lens reduces coma and flattens the field for both viewing and photography. It threads into LUMICON 2" EASY-GUIDERS for effortless installation. This lens is optimized for f/4.5 and reduces aberrations for f/3.5 to f/5 Newtonians. Off-axis images are much smaller, making off-axis guiding far easier and yielding round pinpoint star images in photos. Since star images are sharp over a full 2¼" circle, you can use medium format cameras in addition to 35mm cameras. This zero power lens does not change image scale nor shift focus, and all lens surfaces are multi-coated for highest efficiency. Although designed for photography you may also use this lens to improve image quality in wide-field viewing with low power eyepieces.

LUMICON Coma Corrector/Field Flattener
2" lens **$285.00**
Extension tube for viewing **$26**
2" Easy-Guider™ (state camera) .. **$169.50**

ENCHANCED ALUMINUM DIAGONAL MIRRORS BOOST TELESCOPE PERFORMANCE

LUMICON 1.3" & 3.1" enhanced aluminum diagonal mirrors & 2" star diagonal.
The new LUMICON diagonal mirrors have a special enhanced aluminum coating with a protective overcoating for long life. Visible reflectivity is 95-96% compared to 86-89% for standard aluminum coated mirrors. The extra 8-10% transmission is like adding an inch of aperture! The substrate is fine annealed Pyrex flat to 1/8 wave.

1.32"	**$29.95**	1.52"	**$34.50**	1.83"	**$39.50**
2.14"	**$49.50**	2.60"	**$65.00**	3.10"	**$89.50**

ENHANCED ALUMINUM STAR DIAGONAL

90° star diagonals with above enhanced aluminum mirrors in a CNC machined black anodized aluminum body. Performance far exceeds prism diagonals.
1¼" (1.32" mirror) **$99.50**
2" (1.83" mirror)(see photo above) .. **$159.00**

OXYGEN-III FILTER

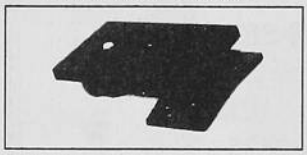
Helix Nebula, NGC 7293 in Aquarius. Bright and easy with Lumicon Oxygen-III Filter.

The ultimate in filter performance! The Lumicon Oxygen-III Filter has a contrast twice as high as the high performance Lumicon UHC Filter™. Use the Oxygen-III Filter for observing the very faintest planetary and diffuse emission nebulae. Also gives incredible views of bright nebulae (like M-27, M-17, etc.) from urban locations. Bandpass is 11nm, transmission is 90% for both O-III lines at 496nm and 501nm.

Filter Type	**1¼"**	**48mm**
Lumicon Oxygen-III	**$99.50**	**$199.50**
Lumicon UHC	**$99.50**	**$199.50**
Lumicon Deep-Sky	**$79.50**	**$119.50**
Set UHC and Oxygen-III .	**$190.00**	**$380.00**

NOTE: The Oxygen-III Filter is not a substitute, but a compliment to the UHC Filter. **1 year guarantee:** You must see nebulae with the O-III filter that are **invisible** without a filter.

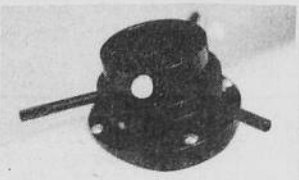
NEW ADJUSTABLE PIGGYBACK MOUNT



LUMICON has just designed a new adjustable piggyback mount ideal for all telescopes of 8-14" aperture. It has **both** vertical and sideways adjustment to allow optical alignment. It was designed to allow mounting of the LUMICON SUPER-FINDER on C-8, C-14, etc., but is ideal for any telephoto lenses or small telescopes.

Deluxe Piggyback Mount **$54.00**
(State Telescope Type)
LUMICON 12x80mm SUPER-FINDER $195.00

NEW! LOW PROFILE HELICAL FOCUSERS



LUMICON® DELUXE NON-ROTATING HELICAL FOCUSER on a 6" telescope.
LUMICON now offers 3 different low-profile helical focusers. They stand only 1¼-1½" above the telescope tube. Use the 1¼" or 2" versions for viewing. Use the 2" non-rotating focuser for convenient photography with the LUMICON 2" EASY-GUIDER™.
Select your desired base-plate shape!
Flat, 7" OD, 9½" OD, 12½" OD, 16" OD, 21" OD, SUPER-FINDER base plate.
LUMICON 1¼" Helical Focuser **$49.50**
LUMICON 2" Helical Focuser **$59.50**
LUMICON Non-rotating Helical Focuser $89.50
3 handles (see photo) for non-rotat. focuser **$12.95**
2" Rack & pinion low profile focuser ... **$129.00**
2"/1¼" adapter w/48mm filter threads ... **$20.00**
2" LUMICON EASY-GUIDER **$169.50**

PROTECTIVE DUST COVERS

Protective plugs (left), vinyl dust covers.
Protect your valuable telescope optics, eyepieces and accessories with these black vinyl covers. Add $1 shipping. Deduct 10%, 2 or more sets.

1¼" O.D. plug, seals focuser	**4/$2**		
2" O.D. plug .	**2/$2**	3½" O.D. plug	**$1.50**
1¼", 1⅜"	**3/$2**	7½"	**$8**
1½"	**2/$2**	9½", 10.4"* ...	**$12**
2"	**2/$2**	12½", 12⅞"* ...	**$15**
3½", 4½"	**$5**	16"*	**$20**
5½"	**$6**	19" (DS-16) ...	**$35**
*Fits Odyssey		21" (Odyssey 17½)	**$35**

MAKE YOUR OWN ASTROGRAPH

FILM HYPERSENSITIZATION KITS†

LUMICON HYPER-KITS™ yield 3-15X film speed gain in long exposures. They are safe & simple to use. Easy HYPER-KIT includes a chamber with all controls and fittings, thermometer, a refillable cylinder of non-flammable forming gas & hand-operated vacuum pump.

†U.S. Patent 4,473,636

MAKE YOUR OWN HYPERED FILM

MODEL 300 HYPER-KIT sensitizes any 35mm film in hours. Best for 2415. Achieves highest possible film speeds **$295.00**

MODEL 600 HYPER-KIT (See Photo) Like the Model 300, but also sensitizes 120/220 larger format film and small glass plates **$350.00**

MODEL 1200 HYPER-KIT is for 4X5" plates and film up to 5X7". Has 2 gas cylinders and includes temperature controller **$595.00**

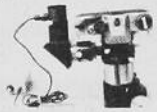
Temperature controller for any HYPER-KIT **$65.00**

Electric Vacuum Pump **$319.00**

GUIDE OFF-AXIS FOR LOVELY ASTROPHOTOS

All **LUMICON EASY-GUIDER™** off-axis guiders† have both radial and 360° rotational adjustments for 5X easier guide-star selection, use 48mm filters, 360° camera rotation, large prisms of bright guide-starts. Specify Camera and Telescope type.
U.S. Patent #4,448,500

NEWTONIAN EASY-GUIDER™



Full aperture. Installs in secs. Specify 2" or 1¼".

NEWTONIAN EASY-GUIDER **$169.50**
3X Relay Diagonal (see photo) **$89.50**
Illuminated reticle eyepiece system .. **$99.50**
Guider for Hasselblad **$350**, Mamiya 645 **$199**

CASSEGRAIN EASY-GUIDER™

For C-8, Meade 2080, Dynamax-8. Includes 50mm achromatic lens for f/5.8 operation —3X shorter exposures! **Superb rich field viewing, too!**
CASSEGRAIN EASY-GUIDER **$225.00**
Adapter for Hasselblad $185, Mamiya 645 **$98**

GIANT EASY-GUIDER™

For Celestron-11, C-14, and the 10" Meade 2120. Includes 80mm clear aperture achromatic lens for edge-to-edge illumination & pin-point star images. F-ratio adjustable f/4-f/11. **Also yields unmatched Rich-Field viewing.**

GIANT EASY-GUIDER..... **$395.00**
48mm DEEP-SKY Filter ordered with any EASY-GUIDER (SAVE $20)..... **add $99.95**
Adapter for Hasselblad adapter **$195,** Mamiya 645, **$119**

WHAT DO YOU NEED?

1. Illuminated reticle eyepiece **$99.50**
Lumicon 12mm eyepiece system has adjustable L.E.D. illumination, dual crosslines, battery pack.
2. Cable release for long exposures .. **$9.95**

3. **LUMICON Quartz Drive Corrector . $219**
Dual-axis drive corrector is essential for astrophotography and/or field use of your telescope. 40Hz/80Hz variable output controls telescope drive. 60Hz Quartz reference ±12VDC Declination control output. Both 110VAC and 12VDC input for home or field use. Declination reverse switch for Newtonians.
Declination motor (state telescope) .. $99
NEW Deluxe Digital Qtz. Drive Correc. **$298**

HYPERSENSITIZED FILM
LUMICON Hypersensitized film is essential for good deep-sky astrophotography. Deduct 10% for 3 or more rolls (mixed o.k.).

Film Type, 35mm	**Exposures**	**Price**
2415, Ultra-fine B&W, red sens.	36	**$10.95**
SR3200, fastest of all, color neg	24	**$13.95**
Konica SR400, fine gr. color neg	12	**$10.95**
3M 1000, fastest slide film	20	**$12.95**
Fujichrome RD100, fine gr. slide	24	**$12.95**
5072, color slides from negs	36	**$6.95**
D-19 B&W Developer	1 gal.	**$6.95**

LUMICON®

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8.00"	$68.00	16.0"	$228.00	8.00"	$26.00	16.0"	$ 92.00
10.00"	$85.00	17.5"	$250.00	10.00"	$32.50	17.5"	$100.75

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2" oculars for a wide field and ultra-bright images

Our selection of giant 2" oculars will meet your most critical viewing needs. Nothing beats these big wide field Königs for total viewing pleasure. Full multi-coating and special non-reflective ocular caps.

32mm or 40mm König-2 ..... **$119.95 ea.**
55mm Plössl **$119.95**

The new "Limited Edition" 55mm Plössl

Simply put, we guarantee this new Plössl will equal or exceed the field of view, edge correction, and resolution of any Plössl made regardless of cost, *or your money refunded, no questions asked!* Built-in eye shield and multi-coated. 2" O.D. **$150.00**

This 7-element 40mm König-2 is in a class by itself!

Referred to by some who have used it as the most impressive 2" ocular ever made, the König 7/70 gives an incredible 70 degree field of view with excellent edge of field correction! Standing over 4-1/2" tall and weighing 1 lb. 4 oz., this ocular will be the crown jewel of your eyepiece collection. As with all University 2" oculars, you get state-of-the-art multi-coating and barrels threaded for 48mm filters. **$235.00**

The wide-angle König-2 leads the field in premium quality oculars!

You told us that the König design just couldn't be improved upon, yet our new König-2 series of 1-1/4" oculars have improved multi-coating and darkened lens edges for breath-taking visual contrast. Special non-reflective black ocular caps. Protective caps on both ocular and barrel ends. The 32mm model uses large 2" lenses set in an 1-1/4" format.

6.5mm, 8mm, 12mm, 16mm ..... **$69.95 ea.**
24mm ..... **$74.95 ea.**
32mm ..... **$99.95 ea.**

An improved 12.5mm wireless Plössl for your most demanding guiding requirements.

This is the one that started the wireless guiding revolution a number of years ago and this new Plössl design gives a greater field and more eye relief. Double crosshair with 0.25mm central box. Red LED with brightness control. Multi-coated optics. **$99.95**

Excellent quality and reasonable prices make these Plössl and Kellner eyepieces value leaders!

Yes, we still make some excellent quality eyepieces for those of us who don't have $300 or $400 to spend on an eyepiece. Our Plössls are the true 4-element design. The Kellners are parfocal. All eyepieces are multi-coated and threaded for standard filters. 1-1/4" O.D. The **Plössls** are available in **7mm, 12mm, and 20mm—$49.95 ea.** The **Kellners** come in **9mm, 12mm, 18mm, and 25mm—$33.00 ea.**

9mm wireless illuminated eyepiece with movable reticle!

This 9mm Plössl is an astrophotographer's dream come true! Micro-adjusters allow you to move reticle within the field of view. Saves hours of work. Special double crosshair reticle also has two concentric rings. Red LED with brightness control. Diopter adjustment. 1-1/4" O.D. Multi-coated. **$129.95**

The exciting new Wide Scan™ offers the ultimate 80° viewing experience.

Now you can enjoy the 80° viewing experience without the excess size, weight, and expense usually found with this class ocular. And it didn't take us 9 lenses to accomplish it! Beautiful panoramic views, excellent pupil correction, and multi-coated optics for the brightest image of all. Special rubber eyeguards standard on all models. The 25mm model has a 70° field with 7 lens elements. 1-1/4" O.D.

10mm–$130.00, 13mm–$130.00, 20mm–$150.00

New from University—Wide Scan 32mm 2" O.D. with an 80 degree field!

This exquisite new 6-element Wide Scan 32mm with its wide, flat 80 degree field yields views of the heavens that are simply breathtaking! Fully multi-coated optics for a bright, high contrast image. Try one of these and you will never go back to ordinary eyepieces again. With one giant step, University Optics takes the lead in innovative eyepiece technology. Introductory price **$235.00**

The Klee.™ Not just another Barlow.

Designed by the master opticians who brought you the Pretoria, the 2.8X Klee has earned a reputation among experienced observers as the ultimate in image amplifiers. Only 2-1/4" long due to its unique 3 element air-spaced design. Multi-coated. **$75.00.**

Correct confusing views of the sky with our image erectors!

Tired of reversed images when trying to use your telescope and star atlas? We have two beautiful image erecting diagnols that can solve your problem. They also convert your telescope for terrestrial use. The 2" 45° Schmidt prism is multi-coated for maximum image brightness. The 1-1/4" model is of the Amici type and has a 90° viewing angle. A thumbscrew holds your eyepiece securely. Price for the **2" unit is $159.95.** The **1-1/4" Amici is $69.95.**

Deep-Sky Binoculars

These are the excellent quality 80mm binoculars we have been selling for years updated with full multi-coating and BAK-4 prisms. Available in 11 or 20 power, they come complete with case, tripod adapter, and collimation certificate. If you are considering binoculars in this class, please give us a call and get the true story. **11X or 20X–$275 ea.**

Return of the classic 20mm Erfle!

We have had many calls from customers looking for nice quality **20mm Erfles** in 1-1/4" O.D. It seems every company has simply stopped making them. Well, now we have them. 5-element fully coated with a 65 degree field **$55.00**

We are also bringing back one of my old favorites, the **40mm Kellner** in 1-1/4" O.D. Gives nice low power and you don't feel bad if it gets lost or damaged at a star party. Fully coated **$33.00**

Color Filters. For bringing out specific planetary features. We offer the most popular colors. **Red, green, blue, yellow, orange, or medium neutral density. $11.50 ea. Full set of six filters—$59.50**

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For those needing a mirror type, we offer the 2" with a full aperture aluminized mirror. Excellent quality with a cast aluminum body nearly 20% lighter than competitive units–**$99.95**

T-Adapter to fit above diagonals to Schmidt-Cassegrain. **$8.95**
1-1/4" Prismatic Diagonal fully coated **$32.95**
Hybrid Diagonal, fits 0.96, takes 1-1/4" **$39.95**

Use this Foucault tester to check your mirror's figure.

A greatly improved version of the Foucault tester we introduced nearly 30 years ago. All parts cut and fully machined. Simple screwdriver assembly. 0.001" measurement dial. We can only guess how many beautiful 1/20th wave mirrors our testers have helped produce over the years. **Kit—$49.95. Fully assembled–$99.95**

A new concept in lightweight, adjustable aluminum mirror cells.

Made from 100% solid aluminum sand castings, the new open cell design lets your mirror reach thermal equilibrium faster. Mirror carrier is spring-loaded with locking screws. 6" or 8" fits any tube from 6.75" to 10". **For 6" mirror–$24.95. For 8" mirror—$29.95**

University Optics now offers a full line of focusing mounts for every telescope maker's most exacting requirements.

Many telescope owners are surprised to discover that the new complex oculars now on the market can never realize their full potential if their field lenses are tilted off-axis due to sloppy focusing mounts. Our entire line of mounts is now made to yield absolute minimum lateral axial movement.

Vega-1, a rack and pinion focuser for 1-1/4" eyepieces.

Basic construction is aluminum with a chrome plated brass drawtube and helical rack and pinion. 4 tension adjustment screws. Racked-in height is 3". Provision for single vane holder. All hardware included–**$49.95**

The Vega-2 is the perfect match for those large Newtonians.

For years, the first choice of custom reflector builders, the Vega-2 offers a helical-cut rack and pinion, all metal construction, and large 1-1/2" focusing knobs. Takes 2" O.D. eyepieces and comes with a 1-1/4" adapter. Racked-in height is 3-3/4". All mounting hardware included–**$72.95**

The Vega-3 and Vega-5 are precision low-profile focusers.

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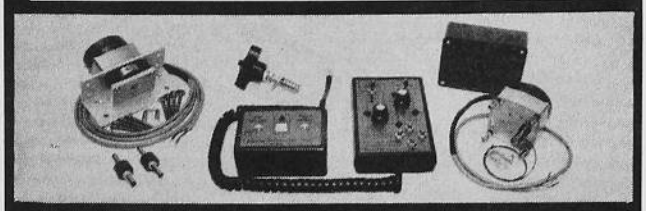

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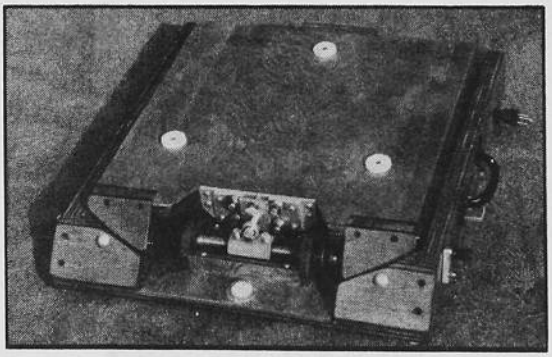

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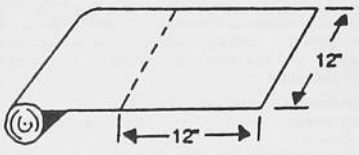

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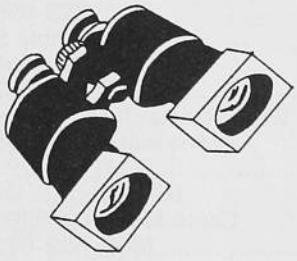

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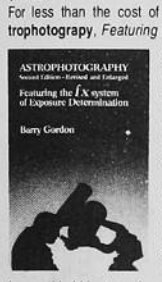

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Ask about the NEW SBIG ST-6 CCD with 9-times larger chip-array and 16 bit resolution!

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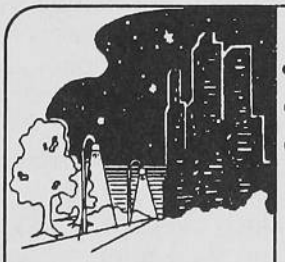


You can help:

- conserve energy
- reduce air and light pollution
- save the night skies for everyone to use and enjoy.

International Dark-Sky Association

For information on *energy waste, light pollution, light trespass, outdoor lighting design* and related issues, or to join, write to the non-profit **International Dark-Sky Association,** 3545 N. Stewart Ave., Tucson, AZ 85716 U.S.A.

Paracorr™ Eats Coma

At Last, a *Universal* Coma Corrector for Parabolic Mirrors

There's no question large aperture reflectors like John Vogt's excellent 30" f/3.8 produce deep sky views rivaling those I've seen in major observatories. But his scope, like yours, is limited in field sharpness. The main offender is coma, an aberration which makes stars look like blurry comets. Visually and photographically, the faster the scope the worse the effect.

If we compensate for coma before starlight reaches the eyepiece, then the best eyepieces will be used to fullest advantage, and a sharp full frame 35mm photograph is possible. In sum, my design goals were:

1. maximum reduction in coma and field curvature without compromising spherical aberration and color correction

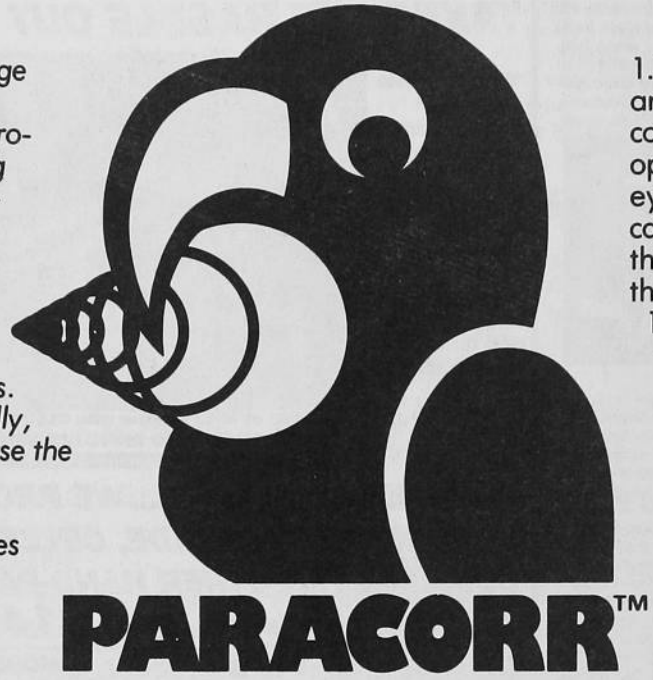
2. major sharpness improvement for all popular focal ratios

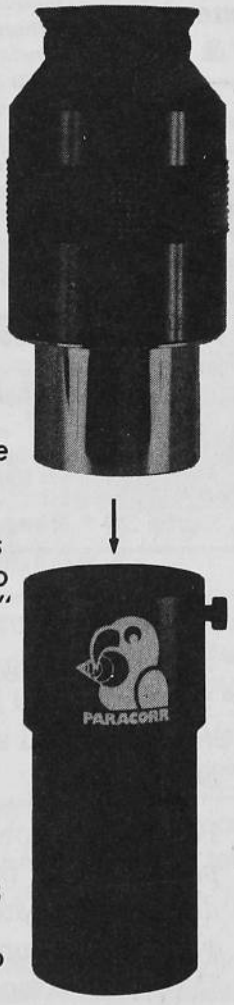
3. equally effective visually or for 35mm film

4. as convenient to use as a Barlow lens

I hope you agree that Paracorr, the coma eater, is the missing link necessary to fully enjoy your "DobNewt."

—Al Nagler





The Formula For Increasing Sharp Field

A perfectly made 13" f/4.5 parabola has only about .1° diffraction-limited field. Now add Paracorr plus a Nagler eyepiece to your f/3.5–f/8 parabola and tremendously increase your sharp field. Extract all the performance the atmosphere and your mirror quality will allow. Since Paracorr tightens and intensifies star images, enjoy resolving globular clusters as they drift right to the edge of your field of view. No more finding the "sweet spot" of focus. The entire field is your "sweet spot"!

Astrophotography

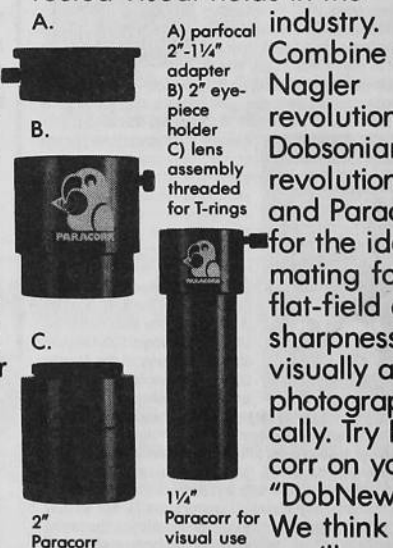
Rival a Schmidt Camera? Mount your 35mm SLR to Paracorr, and the quality of full frame photos will be spectacular since star image sizes are designed to be less than .001 inch over the field for an f/4.5 mirror.

Easy To Use

Paracorr drops in like a Barlow lens. With only a slight 1.15x magnifying factor, an f/4.5 telescope becomes an f/5.17. While optimized for Tele Vue eyepieces, other makes can be used. Of course the better the eyepiece, the better the results. The 1¼" Paracorr is parfocal with most Tele Vue eyepieces. The 2" Paracor requires about ½" in-travel from your current focus location. Can't be simpler for any scope, any eyepiece, and any 35mm SLR camera.

Paracorr—The Missing Link

An optical chain is as good as its weakest link. With the development of 82° Nagler eyepieces, Tele Vue offers the largest, flattest and best corrected visual fields in the industry. Combine the Nagler revolution, Dobsonian revolution and Paracorr for the ideal mating for flat-field and sharpness, visually and photographically. Try Paracorr on your "DobNewt." We think you'll agree that the revolution is complete.



A) parfocal 2"-1¼" adapter
B) 2" eyepiece holder
C) lens assembly threaded for T-rings

Paracorr—More stars, sharper stars, more time to observe. Send $3 for full line literature package.

Tele Vue

20 Dexter Plaza, Pearl River, NY 10965
(914) 735-4044